OECD Food and Agricultural Reviews

Innovation, Agricultural Productivity and Sustainability in the United States

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BETTER POLICIES FOR BETTER LIVES

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Foreword

Innovation, Agricultural Productivity and Sustainability in the United States is part of the OECD Food and Agricultural Reviews series. This review was undertaken at the request of the US Department of Agriculture. We are particularly grateful for the support for this study from the USDA UnderSecretary for Research, Education, and Economics Dr. Catherine Woteki.

The review examines the conditions in which farms and businesses in the United States undertake innovation in the food and agriculture sector to become more productive and environmentally sustainable. It starts with an overview of the food and agriculture sector and outlines development challenges and opportunities (Chapter 2). A wide range of policies which influence incentives for innovation are then examined: economic stability, governance and trust in institutions (Chapter 3); a favourable and predictable environment for investment (Chapter 4); capacities and public services enabling business development (Chapter 5); agricultural policy (Chapter 6) and the operation of the agricultural innovation system (Chapter 7).

US policies are analysed following a framework developed by the OECD as part of its work on agricultural innovation and in response to a request from the G20 in 2012 under the Presidency of Mexico to evaluate the extent to which a wide range of policies facilitates productivity growth and sustainability in food and agriculture. The framework has been applied to Australia, Brazil, Canada, the Netherlands and Turkey and additional reviews are underway or planned.

This review was prepared by Catherine Moreddu and Julien Hardelin from the OECD Trade and Agricultural Directorate, with contributions from Paul O'Brien from the OECD Economics Department, and in close collaboration with The Economic Research Service of the US Department of Agriculture (USDA) under the leadership of James MacDonald and Keith Fuglie. Lihan Wei provided statistical support. Martina Abderrahmane provided editorial assistance and Michèle Patterson editorial and publication support.

In the USDA Economic Research Service, James MacDonald provided the information for Chapters 2 to 5, with contributions from Roger Claassen, Ron Durst, Thomas Hertz, Lorraine Mitchell, Doris Newton, John Pender, and Peter Stenberg. Anne Effland provided the information for Chapter 6 with contributions from Lorraine Mitchell, and Keith Fuglie led the preparation of information for Chapter 7 with assistance from Kelly Day-Rubinstein, Matt Clancy, and Paul Heisey.

The OECD review also draws on OECD analysis in various economic and social policy fields and includes cross-country comparable indicators developed by the OECD and other international institutions, such as the World Economic Forum.

This report has benefitted from detailed comments from James MacDonald, Anne Effland and Keith Fuglie from the USDA Economic Research Service, and discussion with them and their colleagues. Helpful comments were received from Steve Koenig of the US Farm Credit Administration and Gary Alex at the US Agency for International Development, and from staff throughout the US Department of Agriculture, including Neena Anandaranam, Tammy Basker, Harry Baumes, Roger Claassen, Charles Dodson, Larry Granger, Robert Griesbach, Joy Harwood, Kari Heerman, Rosalyn Murphy-Jenkins, Mark Peters, Jim Radintz, Valerie Reed, Ibrahim Shaqir, Robin Shoemaker, Stacy Sneeringer, Curtia Taylor and Kalvin Trice. It has also received valuable comments from Ken Ash, Carmel Cahill, Frank Van Tongeren, Guillaume Gruère, Jussi Lankoski, Jo Cadilhon and Laura Munro of the OECD Trade and Agricultural Directorate. Steve Neff of USDA's Foreign Agricultural Service provided valuable support in launching the project.

This review was declassified by the Working Party on Agricultural Policies and Markets in September 2016.

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Acronyms

ACA	Agricultural Credit Association
ACEP	Agricultural Conservation Easement Program
ACRE	Average Crop Revenue Election
AFRI	Agricultural and Food Research Initiative
AGR	Adjusted Gross Revenue
AIS	Agricultural Innovation System
AMS	Agricultural Marketing Service
APH	Actual Production History
APHIS	Animal and Plant Health Inspection Service
ARC	Appalachian Regional Commission
ARC-CO	Average revenue guarantee based on county prices and yields
ARC-IC	Average revenue guarantee based on individual farm prices and yields
ARMS	Agricultural Resource Management Survey
ARP	Agricultural Research Partnerships
ARPI	Area Risk Protection Insurance
ARS	Agricultural Research Service (USDA)
BAI	Bureau of Animal Industry (USDA)
BCAP	Biomass Crop Assistance Program
BEPS	Base Erosion and Profit Shifting
BIEC	Border Interagency Executive Council
BMP	Best Management Practices
BRDB	Biomass Research and Development Board
BRDI	Biomass Research and Development Initiative
BRIICS	Brazil, Russian Federation, India, Indonesia, China (People's Republic of) and South Africa
BU	Bushel
CAFO	Concentrated Animal Feeding Operation
CAFTA	Central America Free Trade Agreement
CAT	Catastrophic Risk Protection Endorsement
CBO	Congressional Budget Office
CCP	Counter-Cyclical Payment
CIG	Conservation Innovation Grants
CNMP	Comprehensive Nutrient Management Plan
CPI	Consumer Price Index
CRADA	Public-Private Cooperative R&D Agreement
CRIS	Current Research Information System
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
CTA	Conservation Technical Assistance

CTP	Cotton Transition Payment
CSE	Consumer Support Estimate
CWA	Clean Water Act
DDG	Distillers Dried Grains
DHHS	Department of Health and Human Services
DNA	Deoxyribonucleic Acid
DOD	Department of Defense
DOE	Department of Energy
DOJ	Department of Justice
DOT	Department of Transportation
DP	Direct Payment
DPDP	Dairy Product Donation Program
DRA	Delta Regional Authority
EBI	Environmental Benefits Index
ELAP	Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish Program
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ERS	Economic Research Service (USDA)
EU	European Union
EU15	European Union (15 member states in 2003)
EU28	European Union (28 member states in 2016)
EZ/EC	Empowerment Zones and Enterprise Communities
FAR	Farm and Remote
FAS	Foreign Agricultural Service (USDA)
FRED	Federal Reserve Economic Data
FCC	Federal Communications Commission
FCS	Farm Credit System
FDA	Food and Drug Administration
FDI	Foreign Direct Investment
FERC	Federal Energy Regulatory Commission
FFA	Future Farmers of America
FHWA	Federal Highway Administration
FLCA	Federal Land Credit Associations
FLSA	Fair Labor Standards Act
FRIS	Farm and Ranch Irrigation Survey (USDA)
FSA	Farm Service Agency
FSIS	Food Safety Inspection Service
FTC	Federal Trade Commission
FTE	Full-Time Equivalent.
GAO	Government Accountability Office
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GE	Genetically Engineered

GHG	Greenhouse gas
GM	Genetically Modified
GO zones	Gulf Opportunity Zones
GSSE	General Services Support Estimate
HA	Hectare
HELC	Highly Erodible Land Conservation (HELC)
HNRIM	Human Nutrition and Information Management
HT	Herbicide Tolerant
ICHNR	Interagency Committee on Human Nutrition Research
ICT	Information and Communications Technology
IP	Intellectual Property
IPR	Intellectual Property Rights
IR	Insect resistant
ISO	Independent System Operators
IWGPG	Inter-Agency Working Group on Plant Genomics
KG	Kilogramme
LGU	Land Grant Universities
LFP	Livestock Forage Program
LIP	Livestock Indemnity Program
MAL	Marketing Assistance Loan
MBPS	Megabits per second
MFN	Most-Favoured Nation
MILC	Milk Income Loss Contract
MPP	Margin Protection Program
MSFW	Migrant And Seasonal Farmworkers Program
MT	Metric Tonne
N	Nitrogen
NAFTA	North American Free Trade Agreement
NAP	Noninsured Crop Disaster Assistance Program
NAREEEAB	National Agricultural Research, Extension, Education, and Economics Advisory Board
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service (USDA)
NERC	North American Electric Reliability Corporation
NFJP	National Farmworker Jobs Program
NIFA	National Institute for Food and Agriculture (USDA)
NPDES	National Pollutant Discharge Elimination System
NPGS	National Plant Germplasm System
NPT	National Program Plan
NRI	National Resources Inventory (USDA)
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTIA	National Telecommunications and Information Administration
NTM	Non-Tariff Measure

OAQ	Overall Allotment Quantity
OCS	Office of Chief Scientist
OECD	Organisation for Economic Co-operation and Development
OSTP	Office of Science and Technology Policy
OTC	Over-The-Counter
PCT	Patent Co-operation Treaty
PFC	Production Flexibility Contract
PMR	Product Market Regulation
PLC	Price Loss Coverage
PPIC	Public Policy Institute of California
PPP	Purchasing Power Parity
PSE	Producer Support Estimate
PVPC	Plant Variety Protection Certificates
RBS	Rural Business-Cooperative Service
RC	Renewal Communities
RCPP	Regional Conservation Partnership Program
R&D	Research and Development
RD	Rural Development
REAP	Rural Energy for America Program
REE	Research, Education and Extension
RFS	Renewable Fuel Standard
RHS	Rural Housing Service
RIN	Renewable Identification Numbers
RMA	Risk Management Agency
RP	Revenue Protection
RTO	Regional Transmission Operator
RUS	Rural Utility Service
SAES	State Agricultural Experiment Stations
SBA	Small Business Administration
SBIR	Small Business Innovation Research program
SCRI	Specialty Crop Research Initiative
SCO	Supplemental Coverage Option
SGMA	Sustainable Groundwater Management Act
SIT	Sterile Insect Technique
SME	Small and Medium Sized Enterprise
SNAP	Supplemental Nutrition Assistance Program
STAX	Stacked Income Protection Plan
STEM	Science, Technology, Engineering and Mathematics
SURE	Supplemental Revenue Assurance
TAP	Tree Assistance Program
TFP	Total Factor Productivity
TMDL	Total Maximum Daily Load
TSE	Total Support Estimate
TTIP	Transatlantic Trade and Investment Partnership
TVA	Tennessee Valley Authority

US	United States
USDA	US Department of Agriculture
USGS	US Geological Survey
USACE	US Army Corp of Engineers
USAID	US Agency for International Development
USGCRP	US Global Change Research Program
VFD	Veterinary Feed Directive
WEF	World Economic Forum
WTO	World Trade Organisation
WW II	Second World War

Conversion rates

1 acre	=	0.404685643 hectare
1 pound	=	0.453592 kg
1 bushel (maize)	=	25.4 kg (0.0254 metric tonne)
1 cwt (hundredweight, short US)	=	45.359237 kg
1 short (US) ton	=	0.907185 metric tonne
1 (US) gallon	=	3.785412 litres

EXECUTIVE SUMMARY

The US food and agriculture sector is well-positioned to meet the diverse and increasing demand for food, feed, fuel and fibre at the national and global levels. It is competitive and market-oriented, characterised by abundant arable and pasture land, strong and innovative farm and agri-food businesses, and a large domestic consumer market. In addition, high Total Factor Productivity (TFP), largely driven by farm consolidation and the continuous and widespread adoption of innovation, enables sustained agricultural production growth. This report examines the extent to which various policies affect innovation, structural change, and natural resource use, and thereby help maintain current productivity growth and improve resilience to risk, while addressing important sustainability challenges, such as those related to water management and climate change. It also identifies policy areas that would need to be improved.

The economic conditions and overall policy environment in the United States are supportive of investment in food and agriculture, and facilitate the adoption of productivity-enhancing technology. The regulatory environment promotes competition and facilitates adjustment and innovation. Transparency in contractual relationships along the agri-food chain could, however, be improved. US regulations on products and processes follow essentially a product-based approach and are responsive to new issues. The open trade and investment environment facilitates market-driven innovation and knowledge flows in agri-food trade, with the United States a partner in important bilateral and regional trade agreements. Well-developed financial markets and low interest rates promote investment in farm technology. General income taxation is complex, with applied rates lower than theoretical ones. At the farm household level, specific tax provisions reduce farmers' income tax and farm income variability.

Capacity for growth in the food and agriculture sector could be enhanced through improved roads and fixed broad-band infrastructure, although regional differences in access to infrastructure and services do not seem to impede the production and marketing activities of this sector. The labour market provides flexibility to adjust to changes in labour and skill needs, which in turn improves labour productivity. Nevertheless, ongoing labour shortages have reinforced interest in on-farm labour saving mechanisation technologies.

Improving secondary education in agriculture-related topics and increasing its attractiveness to a wider pool of students would also help attract young people to this sector and respond to changing skills needs. Investment in agricultural education at the tertiary level has been significant through the system of land-grant institutions, which connects research, education and advisory services to farmers. In view of the new skill sets needed for the next level of productivity growth and sustainability challenges, traditional agriculture education has expanded to include a wider range of skills and topics, such as natural resource management.

US agricultural policy allows producers to be reactive to market signals, in part due to relatively low levels of support to producers, of which only a very small share is highly production-distorting. US agriculture faces significant risks, but risk management instruments facilitate investment and changes in farm business practices. However they are not cost-efficient at addressing income problems. Moreover, they risk crowding out market-based solutions and own-farm strategies, and may lead to unsustainable choices of production and practices in the short-term. All farm-revenue approaches to risk management would reduce the need for government support by pooling individual commodity risks. Conditional support has encouraged the adoption of environmentally-friendly practices and well-designed agri-environmental programmes have expanded. However, US agriculture faces sustainability challenges regarding water shortages, water pollution and soil erosion in several regions. Moreover, agricultural intensification takes place on land that is not enrolled in the various agri-environmental programmes, which in turn suffer from reduced participation as a result of rising commodity prices, and climate change.

The United States is the world leader in food and agricultural research and innovation. The advances they have made have strengthened US agriculture productivity and benefitted global agriculture. Research has benefited from international collaboration facilitated by researcher exchanges in US institutions, and various research agreements and partnerships. While public expenditure on agricultural research and development has declined, private expenditure has increased dramatically. This, however, is not a perfect substitute for public research given that the latter focuses at earlier stages of research and covers a broader set of social issues (e.g. environmental protection, food safety) that are generally not addressed by the private sector. Innovative policy mechanisms encourage public-private partnerships in research collaboration benefiting food and agriculture. The share of competitive project funding increased to half of all USDA funding for public and private research. Public extension services are integrated in the land-grant system together with research and development. They have responded to a wider range of innovation needs, bringing research-driven innovations to the farm level. Growing societal and consumer concerns regarding new technologies, production practices and animal welfare will require new approaches to build public trust in the solutions that innovation may provide.

Policy recommendations cover four key areas.

- **Improve further incentives for private investment**
  - Reduce transactions costs for farmer participation in contracts with agri-food firms.
  - Review regulations to respond to science and technology developments and changes in consumer and societal demands.
  - Simplify the tax system and make it more transparent; increase reliance on environmental taxation to address agri-environmental issues.
- **Improve further capacities and services for sustainable productivity growth**
  - Increase investment in strategic infrastructure.
  - Facilitate access to broadband.
  - Implement pro-active skills policy and information systems to facilitate movement of the labour force to areas where strong demand exists.
  - Assess the relevance and cost-efficiency of secondary education in agriculture-related areas, and reduce the shortfall of college students needed in the sector.
- **Make agricultural policy more conducive to sustainable productivity growth at the farm level**
  - Better link agricultural policies to clear objectives to reduce policy uncertainty;
  - Continue to reform commodity programmes, and other commodity-specific support measures, to reduce distortions between commodities;
  - Move towards an all farm-revenue approach to risk management.
  - Strengthen the role of the federal government in dealing with sub-national environmental problems.
  - Rely more on the polluter-pays principle and market-based approaches to reduce agri-environmental pressure from agriculture, and develop environmental service markets, such as carbon offsets and water quality credit markets; and
  - Continue to maintain a good information base and analytical capacity to monitor progress, evaluate policies, and guide farmer decisions.

- **Strengthen the food and agricultural innovation system**
  - Maintain and upgrade public research capacity in food and agriculture.
  - Review the efficiency of different funding mechanisms to ensure a higher impact.
  - Consider greater use of mechanisms that incentivise transdisciplinary and system-based approaches, and wider stakeholder involvement.
  - Explore further research collaboration opportunities at the multilateral level and with non-traditional partners.
  - Strengthen the mechanisms that facilitate the development of solutions to better manage natural resources and improve resilience to risks.
  - Integrate food and agriculture in the climate-change strategy.
  - Ensure farmers continue to receive advice that facilitates sustainable management and to adapt to new environmental pressures.
  - Continue funding and improving tools to better monitor research investments and results.

Chapter 1

OVERALL ASSESSMENT AND RECOMMENDATIONS

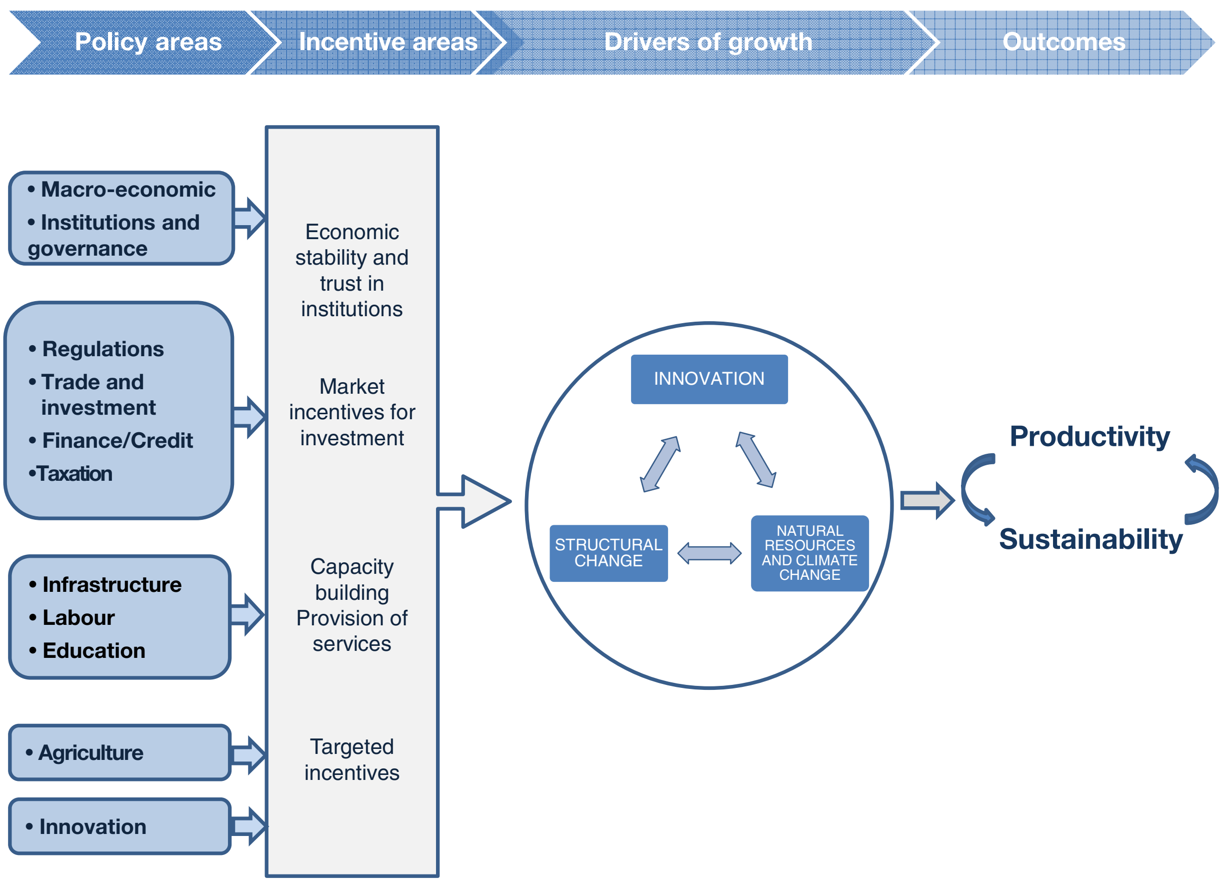
This chapter introduces the framework used to analyse the extent to which US policies foster productivity and sustainability in the food and agriculture sector and presents an overview of findings. Specific policy recommendations are made for each policy area reviewed.

A framework to analyse policies for innovation, productivity and sustainability in the food and agricultural sector

Improving agricultural productivity growth to meet the growing demand for food, feed, fuel and fibre will be achieved through more efficient use of natural and human resources. A wide range of policies affect the performance of the food and agriculture sector, and these need to be considered alongside agriculture-specific policies.

The framework applied in this review considers the full range of policy incentives and disincentives to innovation, structural change, natural resource use, and climate change as drivers of productivity growth and the sustainable use of resources (Figure 1.1).

Figure 1.1. Policy drivers of innovation, productivity and sustainability in the food and agriculture sector



Source: OECD (2015a), "Analysing Policies to improve agricultural productivity growth, sustainably: Revised framework". www.oecd.org/agriculture/policies/innovation.

This review begins with an overview of the characteristics and performance of the food and agriculture sector and the future challenges this sector faces (Chapter 2). A wide range of policies is considered according to the main channels or incentive areas through which they affect drivers of productivity growth and environmental sustainability:

- Economic stability and trust in institutions (justice, security, property rights), which are essential to attract long-term investment in the economy (Chapter 3).
- Private investment, which in turn requires a transparent and predictable environment that balances the interests of investors and society (Chapter 4).

- Capacity building, including the provision of essential public services (Chapter 5).
- Agricultural policy, domestic and trade-related (Chapter 6).
- The agricultural innovation system (Chapter 7).

A policy area can affect productivity and sustainability drivers through more than one channel, and policies can have a positive or negative effect depending on the type and intensity of measures. This review draws on background information provided by the Economic Research Service of the US Department of Agriculture (USDA), recent OECD economic and innovation reviews, and internationally comparable data.

Improving food and agriculture performance to face new challenges requires further innovation

The United States has a large, innovative and internationally competitive food and agricultural sector. Abundant arable and pasture land along with diverse climatic conditions allow for the production of a wide range of crop and livestock products. The sector also benefits from a diversity of efficient family farm enterprises dominated by large operations, innovative managers, competitive agri-food companies, and a large domestic consumer market.

Farm consolidation, facilitated by the adoption of labour-saving technologies, has been rapid with about 3.6% of US farms accounting for about 58% of the total value of agricultural production in 2014. In some sub-sectors, however, such as dairy, poultry and pig meat production, and in some regions, the concentration of production on very large farms has raised issues over the management of income, environmental, animal health, and animal welfare risks.

US farmers can face significant variations in prices and crop yields from year to year, but agricultural policies and tax provisions contribute to reducing the variability of farm revenue or margins, and off-farm activities are increasing and stabilising farm household income. The remaining variability does not seem to slow innovation and US farmers take advantage of high income years to invest in new farm equipment.

US agriculture achieves high levels of productivity and productivity growth, which has accounted for all the growth in agricultural production since 1948. Total Factor Productivity (TFP) growth has averaged 1.45% per year over 1948-2013, and has recovered to that historic average over 2007-2013 after falling off to 0.60% per year in 2000-07. High TFP growth is largely due to the application of a series of innovations in crop and livestock breeding, nutrient use and pest management farm practices, and farm equipment and organisation. Consolidation and specialisation contributed to significant productivity gains, freeing labour, land, and capital resources for use elsewhere in the economy.

Productivity gains have allowed US farmers to produce more with less land and inputs (fertilisers, chemicals and water), leading to increased environmental efficiency nationwide. On average, environmental pressure from agriculture has trended downward during the last decade resulting in the improvement or maintenance of the environment in several areas. For example, the 36% growth in agricultural output over 1990-2013 was achieved with stable land and water use, minor increases in greenhouse gas emissions, and lower nutrient balances, pesticide use and ammonia emissions. There nevertheless remain significant environmental "hotspot" areas linked to agriculture, such as: serious groundwater depletion in California due to intensive pumping; hypoxic zones in the Gulf of Mexico due to excessive nutrient pollution of the Mississippi River (mainly from agricultural sources); local pollution of microbial pathogens and pharmaceuticals in areas with concentrated animal feeding operations; or excessive soil erosion in several regions.

The food and agriculture system is largely market-oriented and responsive to domestic and export demand. It has responded to changes in consumer preference for specific products — e.g. poultry meat, fresh fruit and green vegetables, or food with specific product attributes, such as organic products — by increasing production.

A growing and diversifying demand, at both the national and global levels, provides opportunities for US food and agriculture. Yet market, climate and resource-related constraints create new challenges to meet these demands, while maintaining past levels of high productivity and improving sustainability.

While the nature and magnitude of the impact of climate change at the local level remains uncertain, it is expected to increase the occurrence of extreme weather events that would lead to higher world price volatility and increased water stress in regions already sensitive to water shortages. And although agriculture is expected to contribute to mitigating climate change, while meeting the growing demand for agricultural products, there are growing concerns about the way food is produced, and these concerns will likely place new constraints on agricultural practices.

There are enormous opportunities envisioned by new science, but which will materialise, only if stakeholders and society accept the resulting innovations. To realise the full potential of these opportunities, USDA and other federal agencies must develop improved, transparent, and flexible regulatory and information programmes for biotechnology, animal welfare, and climate change.

Framework conditions are generally supportive of investment and entrepreneurship

The United States is a large and wealthy economy, with well-established institutions to manage economic policies. The US economy was hit hard by the recession and financial crisis of 2007-09, but the government took action to reduce financial risks, to restore short- and long-term credit for economic activities, including agriculture, and to stabilise the economy. Efforts to reduce interest rates did not come at the expense of higher inflation. The US economy recovered slowly, as the sharp reduction in household wealth led to reduced consumption expenditure. Since 2010, macroeconomic indicators have returned to more stable levels: output has surpassed pre-crisis levels and is expected to continue to grow at about 2% per year; private-sector job creation has reduced the unemployment rate; and fiscal sustainability has been restored, although the accumulated federal debt remains high as a percentage of GDP.

The reduction in the value of the USD compared to the currencies of its competitors, notably the EUR, boosted the performance of US agri-food exports between 2004 and 2014, although the exchange rate appreciation since 2015 has had the opposite effect. While access to credit was reduced during the financial crisis, low interest rates since have facilitated investment in food and agriculture, as in other sectors. In addition to facilitating the purchase of innovative technology, low credit cost contributes to raising land values, thus increasing farmers' wealth while slowing new entries into the sector. The sharp reduction in unemployment could indicate a general labour shortage, which is likely to affect availability of farm-hired labour.

US institutions have well-defined governance responsibilities, shared between federal, state and local governments. According to business leaders, who overall rank US institutions close to the OECD average, they maintain secure property rights for private investment and an independent judiciary system. Declining trust in institutions and the political polarisation of US citizens is, however, a growing concern as it could hamper the introduction of new policies that facilitate the diffusion of new technologies in food and agriculture and improve environmental performances.

The regulatory environment for entrepreneurship has long been one of the least restrictive among OECD countries, and US companies operate in a competitive environment that is conducive to investment and productivity growth, with little state control or public ownership of industries. There is no state ownership of commercial farms and virtually no state ownership of food processing firms.

Competition policy facilitates adjustment and does not slow market-driven consolidation. Anti-trust policies aim to ensure that high concentration does not lead to the exercise of excessive market power, in the form of restraints on output that would lead to lower prices paid to farmers or higher prices charged to them for inputs. Some cooperatives have been granted limited immunity from anti-trust laws, permitting members to jointly process, prepare for market, handle, and market their commodities, and to jointly purchase inputs. This was viewed as a way for farmers to react against monopsony power exercised by processors and other market intermediaries. The issue of concentration in food and agriculture attracts, however, widespread attention that has led to investigations on the practices of input, processing and retail firms. Some agricultural cooperatives have also faced allegations that they have taken actions to limit production and raise prices.

A higher level of transparency in contractual relationships within the agri-food system would improve the functioning of markets. Increasing vertical coordination (including via contracting) in the agri-food chain could potentially lead to a lack of transparency and the exercise of market power. A review by the Economic Research Service of the USDA suggests *"…targeted policies to address potential negative effects associated with thinning markets could include: 1) facilitating contracting by establishing a common contracting format in each market that uses clear language to communicate terms, reducing transactions costs and improving the footing of small producers; 2) improving data collection and dissemination of information on prices and price mechanisms, quantities transacted, and the size and number of market participants; and 3) providing production and marketing advice to producers through public extension services.*" (Adjemian et al., 2016).

Regulations on access to and use of natural resources mostly take place at the state level, with varying types of policy responses in terms of stringency, instrument choice, and priorities. Land and water rights are exclusively regulated at the state level and vary by state depending on the availability of resources. This allows regulations to be more tailored to local conditions. In several cases, however, incentives to impose regulatory constraints are lacking, and this could potentially lead to the unsustainable use of local resources. Increasingly, the Federal Government is more directly involved in areas that have major issues (e.g. Chesapeake Bay and California).

The federal approach to agri-environmental policy challenges relies less on regulation to improve farm environmental management practices than on positive financial incentives and other economic instruments. Direct federal environmental regulation affecting agriculture is limited to a few areas. These include mainly regulation of concentrated animal feeding operations; regulation of standards for organic farming; and regulation regarding pesticides sales and use. The stringency of the overall US environmental policy has increased, but remains lower than the OECD average — lower than in Canada and countries of Northern Europe, but higher than in Australia and some large EU member states. US agriculture is excluded from the scope of some federal environmental regulations (such as Greenhouse Gas (GHG) reporting, or emissions of particulate matter).

Federal regulation on manure management practices in livestock production has reduced the intensity of manure application. This is the main agri-environmental regulation at the federal level. While standards are set at the federal level, enforcement is carried out by individual states. Larger animal feeding operations must have a comprehensive nutrient management plan that identifies site-specific practices. Consolidation of production in larger operations concentrates manure in fewer locations, but regulations appear to have an impact on their manure management practices with manure applied per acre of land decreasing significantly in both poultry and pig meat production. However, smaller operations are generally not regulated, and newly constructed pig operations tend to cluster just below the size threshold for regulation, and thereby avoiding regulation.

Regulations on products and processes are generally favourable to innovation to enhance sustainable productivity growth, while ensuring food and environmental safety. US regulations follow essentially a product-based approach. Various government agencies implement regulatory programmes aimed at agricultural pest and disease management, environmental regulation regarding chemical use, the regulation of agricultural biotechnology and the regulation of livestock drugs. There are clear mandates and procedures to carry out inspection, control and prevention tasks, which increasingly require innovative arrangements and joint actions with other state and federal agencies, as well as with other national governments and the private sector. For example, the agency in charge of pest and disease control engages in public-private partnerships with private firms, academia, and with farms in support of surveillance activities and control pursuits.

Biotechnology products, as any other products, are regulated according to product characteristics rather than production methods. A USDA agency regulates the importation, interstate movement, and field testing of genetically engineered (GE) plants and organisms that are or might be plant pests: a regulated plant cannot be introduced into the environment, even for field testing, without agency authorisation.

Regulatory frameworks and guidance are being reviewed with a view to facilitating new developments, while maintaining trust in the system. Gaps remain in the existing regulatory system regarding accidental contamination from GE crops, with several high-profile cases leading to the closure of important export markets. In addition, current regulations do not explicitly account for coexistence issues; for example, how to prevent the commingling of GE varieties with organic and non-GE crop varieties, which would impose economic damages on the organic and non-GE growers. Even as the existing regulatory system adapts to current challenges, new developments in biotechnology promise new types of products, as well as new types of market and scientific risks. The coordinated framework used to regulate biotechnology products is thus being reviewed to address regulatory gaps regarding contamination and to respond to biotechnology developments.

Growing antimicrobial resistance raises issues about the widespread use of antimicrobial drugs in livestock production. In response, the US Food and Drug Administration (FDA) introduced two important changes in the marketing of antimicrobial drugs to be implemented as of 2017. First, the use of specific drugs classed as medically important for human health will no longer be approved for growth promotion or production purposes. Second, all use of such medically important drugs in livestock production will be placed under veterinary supervision with attendant approvals and maintenance of records. The adoption of these regulations is expected to reduce the use of antimicrobial drugs in livestock production and to contribute to slowing the spread of resistance to human and animal pathogens.

Food label claims are likely to increase in response to consumer interest in the production process. At present, USDA is responsible for approving labels on meat products, including those that concern use of antibiotic, and to provide verification services for animals raised according to certain specified production practices, including those that forego antibiotics. The USDA is faced with the challenge of defining the substances that are to be classified as antibiotics and defining precisely what a specific label claims means in ways that are informative and useful for consumers. The government may also have to regulate additional labelling.

The trade and investment environment is relatively open, although there are restrictions in certain sectors. Open, well-functioning markets facilitate knowledge flows embedded in agri-food trade and Foreign Direct Investment (FDI), as well as the adoption of innovations that foster productivity growth at all stages of the food supply chain. As a competitive net exporter of many products, the United States has traditionally been open to trade and active in promoting open trade in multilateral fora. Import tariffs are relatively low, except for some agricultural commodities. However, agricultural products are subject to import licensing to protect against the entry of pests and diseases, and strict quarantine and inspection imposes costs that are partly covered by user fees collected at ports of entry. In addition to being part of numerous bilateral agreements, the United States participates in major regional trade agreements with Northern and Central American countries, has concluded negotiations on the Transpacific Trade Partnership and is in the process of negotiating a new transatlantic partnership (TTIP). Barriers to trade and investment are in line with the OECD average and the country performs well in trade facilitation. But there are significant restrictions on foreign mergers and acquisitions in certain sectors and on foreign provision of legal and transport services. Some barriers to Foreign Direct Investment (FDI) exist, but not in agriculture and food. FDI is low in agriculture, but as a result of large corporate mergers, inwards stocks of FDI in food have almost tripled in recent years.

Interesting initiatives have been implemented to facilitate trade. These include: the establishment of a single-window application across all agencies through which traders can submit electronic data for importation and exportation, and the creation of a Border Interagency Executive Council (BIEC), which is in charge of developing common risk management principles and methods; developing policies and processes to improve and accelerate electronic data treatment, in consultation with stakeholders; encouraging other countries to develop similar single window systems to facilitate sharing of data, and assessing opportunities to facilitate electronic payments of duties, fees and taxes.

Access to finance has been maintained despite the financial crisis. The United States has a very large and well-developed financial sector that maintains close links to global financial markets and scores among the OECD top-five performers in terms of access to loans and financial services. While there exists a diversity of financial intermediaries (such as banks, pension funds, insurance companies, and investment funds), commercial banks and the Farm Credit System (FCS) account for over 80% of all lending to the farm sector.

Government farm loans target farmers with limited access to credit and account for a very small share of total farm loans. The Farm Service Agency (FSA) of the USDA directly provides ownership and operating loans to family farmers, emergency loans for losses from natural disasters, and conservation loans to finance completion of a conservation practices in an approved conservation plan. FSA direct loans and guarantees are directed to farmers who would not qualify for loans from commercial lenders, typically because they have little wealth and limited farming and credit experience. A share of direct loans is set aside for beginning farmers and ranchers and minority loan applicants to help renew and diversify the farm population.

Specific tax provisions reduce farmers' income tax rates and farm income variability, and thus increase their capacity to innovate. The federal income tax has the greatest potential impact on investment, management, and production decisions in the agricultural sector compared to other tax provisions. Most farms are taxed under the individual income tax. Farmers benefit from both general tax provisions available to all taxpayers and from provisions specifically targeted to farmers. In general, income from farming is taxed more favourably than income from many other businesses. Some of these favourable provisions include the current deductibility of certain capital costs, capital gains treatment of proceeds from the sale of farm assets, cash accounting, and farm income averaging. These and other provisions reduce the farm income tax base, allow some farm income to be taxed at reduced rates, and contributes to smoothing annual income variations. Most agribusinesses are large corporations and are taxed under the corporate income tax structure. The United States has the highest corporate income tax rate among OECD countries, but a variety of special provisions narrow the base of corporate income that is subject to tax. Taxation does not impose excessive costs on hired labour. Given the complexity of special tax provisions in the US economy, it is difficult to evaluate the impact of preferential treatment of agriculture. Tax incentives for R&D are relatively lower than direct support to R&D (see innovation section).

Recommendations to improve incentives for private investment

- Establish a system to monitor with greater regularity the impact of high concentration of firms in the agri-food sector.
- Reduce transactions costs for farmer participation in contracts with agri-food firms by establishing a common contracting format in each market; improve data collection on prices and quantities; and provide production and marketing advice to producers through public extension services to improve the participation of small producers, as suggested in Adjemian et al. (2016).
- Improve water management regulations in agriculture to avoid over-use of water and to increase resilience to current and future scarcity, as well as ensure that water users pay the right price.
- Review regulations to respond to science and technology developments and changes in consumer, societal and market demand. Increase transparency and discussion with stakeholders concerning regulations on product and processes .
- Interesting initiatives have been implemented to facilitate trade via the use of single window and electronic data management. Sharing this experience with other countries would further contribute o international trade facilitation.

- Numerous exemptions to corporate and personal income tax distort economic activities and are often regressive. The 2015 OECD report *Going for Growth* (OECD, 2015b) includes recommendations to reduce statutory marginal corporate income tax rate and broaden its base, eliminate regressive exemptions, and to simplify eligibility procedures and record-keeping requirements.
- The OECD *Going for Growth* report (OECD, 2015b) also recommends increasing reliance on environmental taxation. There is scope for applying this recommendation to agricultural activities.

Capacity and services for sustainable productivity growth could be improved

Transport infrastructures facilitate the movement of agro-food products and farm inputs, within the country and to export points, contributing to productivity growth. The transport network is relatively well-developed, but road infrastructure seems to have deteriorated since the 2008 crisis. In addition, responsibility for funding and operating the transport infrastructure vary by means of transport. Road construction and maintenance is funded by federal, state and local governments, while railways are privately maintained and operated. This lowers private costs of road transport over railways. Resources for road infrastructure originated mainly from a gasoline tax, but are now more diversified. OECD (2016) suggests a number of alternative sources of funding for road infrastructure, including using federal programmes and public-private partnerships, and improving user fees so that negative externalities are addressed more effectively. Train freight has become more concentrated, and the issue of rail competition remains important for agricultural shippers, in particular when waterways are not an option.

Telephone and internet coverage and use are unequal across regions and by technology. The quality of Information and Communication Technology (ICT) infrastructure ranks slightly above the OECD average, but the number of mobile telephone subscriptions per capita is below the OECD average and fixed broadband access is unequal across the country. In addition, fixed broadband communication is generally at lower speed and at higher costs than the OECD average. However, high speed mobile telephony covers over 95% of the continental territory. While Internet development has been mainly privately funded, recent federal programmes aim to enhance household Internet participation. Potential for greater competition is emerging in the fixed-line broadband sector with new entrants to the market beginning to create or augment existing networks.

Electricity supply comes from diverse sources, some of which increase off-farm income opportunities to rural and farming populations. Electricity supply is organised into five networks which cannot be easily interconnected. Some deregulation started in the electricity market in the 1970s when independent power producers began to sell electricity to utilities, but deregulation has slowed down as issues regarding monopoly power have emerged. The diversification of energy supply away from coal as a fuel source towards natural gas from fracking and wind power has benefited some farmers, who receive income from energy leases (natural gas, oil or wind). A number of large livestock farms also produce energy from anaerobic digesters. The environmental and climate change impacts of changes in energy sources are complex and would need to be assessed.

Farming activities are not impeded by regional differences in access to infrastructure and services, and benefit from an abundance of land in less-well serviced areas. The USDA is the lead federal agency for rural development programmes providing loans, grants and technical assistance to support development of rural companies, utility infrastructure and housing and community facilities. Over the years the share of assistance under grant and direct loan programmes has declined, while guaranteed loans have increased. Other federal agencies such as the Department of Transport or the Small Business Administration provide assistance to rural communities, and state and local governments influence rural development through programmes, investments and tax incentives.

The US labour market has one of the least restrictive employment protection legislation among OECD countries, which facilitates, in particular, temporary forms of employment. Agricultural employment has been steady for the last decade and includes full-time and part-time farm household members, as well as hired labour.

The well-functioning labour market gives the agri-food sector the flexibility to adjust quickly to changes in labour and skills needs, and thus increase labour productivity. It also facilitates off-farm employment by farm household members. This responds to long-term socio-economic developments in the sector and the whole economy, as well as shorter-term needs, and has the capacity to attract and retain talent. This is particularly important for agricultural innovation as the US innovation system attracts well-qualified nationals and foreigners. Agriculture is exempted from some rules regarding overtime pay, minimum salaries on small farms, part-time farm household members, and safety protection (although farming is one of the activities with highest safety risks).

Immigration policy matters for agriculture as about half of hired crop farm workers are foreign-born. Immigrants, in particular seasonal workers, are particularly important for fruit and vegetable production. New immigration laws, more vigorous enforcement of immigration laws, and changes in the incentives to migrate from Mexico have slowed immigration so that the hired farm workforce has become older and more settled. This has raised concerns among fruit and vegetable growers, who are generally reliant on seasonable immigrant labour. In response to labour shortages, specific visas are being issued to fill seasonal needs. This system is increasingly popular and provides a timely response. Legislation is proposed to grant legal status to unauthorised immigrants, although this could increase their mobility out of agriculture. A federal programme provides skills training, assistance to job search, and other services to immigrant farm workers in order to reduce unemployment and stabilise their agricultural employment (there is a good success rate as measured by the percentage of people who entered and kept employment).

Labour shortage reinforces interest in labour-saving mechanisation technologies, which have traditionally responded to higher farm labour costs and contributed to Total Factor Productivity (TFP) growth. In some sectors, these technologies have also permitted higher engagement of farm operators in off-farm activities. While public research had disengaged from this area, there is now renewed interest to respond to foreign labour shortage. The USDA, for example, has reinvested recently in improved mechanisation for the fruit and vegetable industry.

The United States is a global leader in tertiary education, but performs poorly below secondary level, despite the high level of investment. Not only does the innovation system require well-educated researchers, teachers, extension officers, and managers, but a high level of general and scientific education facilitates acceptance of technological innovation by society as a whole. State and local government have primary responsibility for administering and funding educational institutions, with state governments setting educational standards. Public schools account for over 90% of enrolment in elementary and secondary schools, but private institutions account for about one-third of professional and graduate enrolment. However, educational attainment has not progressed as fast as in other OECD countries. Nevertheless, high enrolment and education attainment in the United States has been a driving force of productivity growth. Tertiary education offers a particularly high pay-off in the US labour market. US leadership in tertiary education is reflected in the high number of foreign students it attracts, including in agriculture. In contrast with the high quality of tertiary education, skills performance among students and the labour force with below secondary level education is below OECD average, although the United States spends more per student than most countries. The ability to meet labour market needs is not considered high, although low unemployment levels suggest adjustment does occur. A lower percentage of students graduate from science and engineering programmes than on average across OECD countries. Moreover, the gender gap in favour of men can be partly explained by the lower share of women in high earning activities such as engineering and computer sciences. Previous OECD economic surveys recommended increasing tertiary education attainment in Science, Technology, Engineering and Mathematics (STEM) fields to boost innovation and productivity. The Every Student Succeeds Act was introduced in 2015 to improve access to quality secondary education so that students are better prepared for STEM tertiary studies.

Investment in education for agriculture is significant, including through the system of land-grant institutions, which combine research, education and extension activities. Agricultural education starts in secondary schools, with a diverse offer that combines classroom and laboratory instruction with experiential learning. Most formal food and agricultural education programmes are found in small towns and rural areas. Reaching out to non-rural students would enlarge the pool of candidates, and could remedy the projected shortfall of US college graduates in food, renewable energy and environmental specialities compared to job openings. An extensive post-secondary programme of agricultural research and education is operated primarily through a system of land-grant institutions. These efforts do not necessarily benefit the primary sector as principal operators of commercial farms have lower educational attainment than the private industry average: While some graduates in agricultural, environmental and food science will take jobs in farming, most will work in agricultural services, agri-food firms, government and academia.

The agricultural education system faces a number of challenges, arising in particular from the broader range of knowledge required in this sector. For example, it needs to move beyond production agriculture towards food and nutrition, natural resources and general knowledge such as ICT, business management and socio-economic issues. There is a wide range of courses covering all these areas in the United States, but curricula are often highly specialised in science fields, in particular at the tertiary level, and leave little space to acquire additional knowledge that is increasingly important in research (for example ethics, economics and business management). Moreover, it needs to attract students in areas where jobs will be created, and adapt curricula accordingly. Education is also expected to contribute to improved understanding of agriculture and food in the general public, and this will be increasingly important to facilitate adoption of useful innovations. Finally, given the diversity of the US system, improving coordination in the development, implementation and monitoring of programmes at the secondary level would increase the impact of innovations. Developing consolidated information would also help to identify possible resource gaps, and to enhance the capacity to draw lessons from various experiences.

Recommendations to improve capacities and services for sustainable productivity growth

- Boost investment in infrastructure and use federal programmes to encourage co-ordination across state and local jurisdictions (OECD, 2016). Strengthen competition among transport providers, and use competition policy to prevent unfair pricing behaviour, and remove obstacles towards greener supply, and use market-based incentives when appropriate.
- Continue to facilitate access to broadband and the management of information given that data-intensive knowledge is increasingly important to improving productivity and sustainability in food and agriculture. Competition authorities should act to preserve competition in fixed broadband in the same way they have done so for wireless broadband. In addition, prohibitions in some states on municipalities creating their own networks should be removed.
- Implement pro-active skills policy and information systems to facilitate the labour force moving into areas with strong demand, such as agri-food and nature management.
- Assess the relevance and cost-efficiency of secondary education in agriculture-related areas in providing the skills required for a modern economy. Improve coordination and consolidate the information base to facilitate evaluation of different initiatives, sharing of experience to achieve higher levels of performance. Sharing experiences with other countries could also be useful.
- Increase public knowledge of science, in particular of biological, agricultural and food processes, through education and communication, to facilitate acceptance of innovation and the expression of informed choices.
- Reduce the shortfall of college students in this sector by reaching out to non-traditional agricultural students. Use other mechanisms that involve stronger coordination with the private sector, and implement specific training programmes. Consider the introduction of quality requirements to receive federal support, and common core standards in primary and secondary education.
- Increase exposure of agricultural science specialists to social sciences, which should be included in agricultural science curricula as they are increasingly important to improving the relevance of food and agricultural innovation, and to ensuring that research leads to economically useful and ethically acceptable innovations.

Agricultural policy is generally conducive to innovation

Producer decisions respond largely to market signals, although resource allocation across commodity sectors could be improved. Current producer support levels in the United States are modest by OECD standards, although in part due to higher world commodity prices. In recent years, US producer support has accounted for less than 10% of farm gross receipts. Indeed, since the mid-1980s, the share of US support to producers in gross farm receipts has been consistently well below the OECD average and the share of the output and input-based support that is most distorting to production and trade is one of the lowest among OECD countries. However, distorting support is concentrated on a small group of products, and a large share of US support is linked to specific commodities, including insurance programmes, and this may have created some distortions among commodities leading to inefficient resource allocation. Sugar, cotton and milk programmes in particular have generated higher support than is available for other commodities and have retained resources in these sectors. The dairy policy was reformed in 2014 and once fully implemented, it will be interesting to monitor whether market price support is effectively lower. In this case, the sugar policy will remain the only commodity programme that provides significant price distortions. Some commodity producers receive, however, higher support rates than others, as shown by commodity-specific transfers as a percentage of farm receipts of the commodity. Cotton producers, for example, can receive higher insurance premium subsidies.

Mandates for blending biofuels with gasoline for transportation fuel use have affected some US commodity markets. The Renewable Fuel Standard (RFS), which sets annual mandates for four nested biofuel categories, is the primary policy supporting biofuel use and development. As conventional, maize-based ethanol makes up around 98% of blended biofuels, the mandate has increased demand for maize, thereby stimulating production. The share of maize used for ethanol has more than tripled since 2005 to reach a peak of 43% of production in 2012 followed by a gradual decrease to 37% in 2015. At the same time, the share of maize used to feed animals has decreased and been partially replaced by distiller dried grains, a co-product of the ethanol dry-milling process. Blending obligations are allocated to blenders and importers in the form of Renewable Identification Numbers (RINs) that are transferable between firms. Transferability enhances the efficiency of meeting blending obligations at the national level.

Various programmes promote the development of bioenergy or bio-based products, with a current focus on those based on the non-commodity sources, biomass and cellulose. In addition to the specific mandates for advanced biofuels (with a minimum GHG reduction of 50%), these include financial incentives for domestic production, funding for research projects in this area, and loans and loan guarantees for the development of new and emerging technologies. Past programmes stimulated both public and private research on innovation on biofuels in a context of high oil prices. However, current efforts are slow to translate into the development of non-commodity, advanced biofuels and the 2016 OECD-FAO Agricultural Outlook (OECD and FAO, 2016) assumes that by 2025, only 2% of the cellulosic mandate as defined by the Energy Independence and Security Act (EISA) of 2007 will be fulfilled.

Agricultural policy places few restrictions on structural adjustment in farming. This has enabled the development of large and productive farms, although some exceptions remain. Marketing orders apply for a number of commodities, including milk and some fruits and vegetables, but constrain production volumes only one product. Marketing allotments exist for sugar, but have not been binding for a number of years. More generally, while support levels are relatively low, a large share is based on land and raises land values, thereby increasing the costs of farm entry and expansion.

Risk management instruments facilitate investment in the medium term. Over the five-year period of each farm bill, farmers gain a clear view of instruments and support available and can choose a level of risk coverage. But major changes can occur between Farm Bills in uncertain directions, adding policy risk in the longer-term.

Support aiming to reduce income variability is not cost-efficient at transferring income to farmers. The increasing emphasis on insurance and risk management policy tools is an approach to providing support to farmers, but is not cost-efficient as these instruments generate high transactions costs and rent-seeking behaviour by farmers and insurance companies. Insurance subsidies may lead to unsustainable choices of production and farm practices in the short term. They may also crowd out on-farm diversification strategies. In general, insurance subsidies risk crowding out market-based solutions and own-farm strategies, and may transfer part of the risks that should be borne by farmers onto the public budget. More generally, support that aims to reduce income variability goes to large farms, which on average have higher incomes and assets than most US households.

Over time, insurance programmes have evolved to offer more options to farmers in terms of the commodities covered, and the risk coverage rates and traditional crop yield insurance has been complemented by revenue-based options, which take account of the natural hedge between price and yield of a commodity. Increased producer choice of risk management programmes allows programme coverage to be tailored to producers' individual risk management preferences. Programmes are also targeting to a greater degree support to assist in losses and reduced revenues, and away from fixed decoupled support. Nevertheless, insurance programmes remain commodity-specific. Moving to an all farm-revenue approach would exploit differences in price and yield variability across products, and reduce government costs to pursue the same stabilisation objective.

Agri-environmental programmes focus increasingly on working land. Agri-environmental incentives include mandatory conservation compliance for participants in most farm programmes, and voluntary programmes that include both land retirement and the adoption of land preservation and environmentally-friendly production practices on working land. Government expenditure originally focused on the retirement of fragile land from production. Since 2002, however, the share of expenditure focusing on working land has gradually increased and should rise to above 50% of all conservation spending over 2014-18.

At the same time, the share of producer support conditional on the adoption of environmentally-friendly practices has doubled since the mid-1990s. Compliance incentives have varied over the years as economic conditions have changed and agricultural policies have evolved. For example, crop insurance premiums were linked to compliance in 2015 in recognition of their growing importance in the policy mix. Producers may receive technical assistance to implement conservation practices. Innovation grants are also available to fund innovative projects as part of some programmes. These components offer the opportunity to discuss innovation needs with programme participants.

The design of agri-environmental programmes has improved, with better targeting of a broader set of environmental issues. Agri-environmental programmes are better targeted to specific objectives and tailored to the most effective means of reaching those objectives. There is evidence that these measures have had significant impact on reducing soil erosion, partly due to the adoption of less erosive practices such as conservation tillage and crop rotations in crop production. Originally focused on soil and water quality and conservation, agri-environmental programmes have since expanded to include wildlife habitat, air quality, carbon sequestration, energy conservation, and preserving farm and ranch lands.

Agri-environmental programmes face three challenges: slippage effects, declining participation, and climate change. There is evidence that these programmes, by retiring agricultural land from production, have stimulated intensification in planted areas, and thus intensive margin effects may have cancelled the direct positive effects, i.e. the slippage effect. Rebalancing agri-environmental regulations and incentives towards the polluter-pays-principle would contribute to reducing this unintended effect. In recent years, incentives from agri-environmental programmes have not been able to counter increasing commodity prices, thus reducing participation in spite of an increasing or nearly stable budget. The impact of reduced participation on future sustainability needs to be monitored carefully. Agri-environmental programmes can have positive side-effects on climate change adaptation and mitigation. Moreover, several initiatives such as regional climate hubs and research programmes have been developed to help farmers cope with the challenge of adapting to climate change in the agricultural sector. These efforts may pay off over the medium and long term, and should be encouraged and developed if proven to be effective.

The information base and analytical tools to monitor progress, evaluate agricultural and innovation policies, and guide farmers' decisions should be preserved from budget cuts and even developed using various sources of open data. The US government has played an important role in the collection of information, including long time series and rich survey data. This allows for the formulation of evidence-based policies. It is particularly important to identify the determinants of the adoption of specific types of innovation and to strengthen the capacity of farmers, or farmer organisations, to formulate their needs and participate in knowledge networks. Fostering the development of internationally comparable indicators would also help benchmark the US situation and facilitate the exchange of experiences.

Recommendations to make agricultural policy more conducive to farm level sustainable productivity growth

- Better link agricultural policies to clear objectives to facilitate policy evaluation and reduce policy uncertainty.
- Continue to reform commodity programmes, including those market price support measures and other commodity-specific support measures that remain to reduce distortions
- Evaluate risk management instruments to ensure they do not transfer risk to the public budget that should be borne by farmers, and to monitor they effectively lead to better targeting of risk. Move towards an all farm-revenue approach to exploit differences in price and yield variability across products, thereby reducing government costs for a given objective as well as removing distortions across commodity sectors.
- Strengthen the role of the federal government to coordinate and facilitate the implementation of efficient approaches to state or local agri-environmental problems. Provide guidelines, mechanisms to share experiences, and matching funds if appropriate.
- Increase the scope of the polluter-pays-principle to address environmental pressure from agriculture to free funds for more ambitious agri-environmental targets where appropriate, and reduce unsustainable intensification on non-enrolled land (slippage effect). Consider market-based approaches to reduce environmental pressure and the development of environmental service markets, such as carbon offsets and water quality credit markets.
- Continue to improve the design of agri-environmental programmes, using best available scientific and economic evidence basis, to better target and tailor to actual needs. Explore the feasibility of introducing output-based targets through pilot programmes.
- Continue to maintain a good information base and analytical capacity to monitor progress, evaluate policies and guide farmer decisions, with specific attention to innovation adoption and environmental practices. Foster the development of internationally-comparable indicators and open data. Continue to improve information on the potential impact of climate change at the local level through research and scenarios analyses to help adaptation of farming systems.

The government role in the food and agricultural innovation system is changing

The United States is the world leader in food and agricultural research and innovation, as evidenced by the size of public and private investments in this area, the scientific achievements generated, and the foreign students and researchers the innovation system attracts. A wide range of innovations has contributed to improving US agricultural productivity, ahead of other countries, and to growing farm and agri-food firm consolidation, thus improving the competitiveness of the sector in world markets. Exports of US science and technologies have also benefited greatly agriculture in other countries, including through development aid for agricultural innovation.

Higher research capacity in the world offers further collaboration opportunities to US research. Cross-country collaboration is increasingly important to address transnational and global issues, such as pest and disease control, climate change and food security. US public research institutions have placed greater emphasis on international collaboration to address shared challenges, although this represents a moderate share of all US agricultural research outputs. The USDA Agricultural Research Service (ARS) has formal agreements with nearly 60 countries for research collaboration, and maintains long-term bilateral research agreements with key research partners, including the People’s Republic of China (“herafter China”), Brazil, Israel and Korea. Cooperation is facilitated in countries with a significant number of researchers having studied in US universities. Multilateral partnerships have been particularly effective for controlling agricultural pests and diseases that threaten whole regions of the world. US research institutions also participated in international climate-related initiatives launched recently.

Investing in agricultural innovation systems to promote food security in low income countries remains a priority. Agriculture has been a major part of US scientific and technical assistance to developing countries, but its role diminished in the 1990s. The launching of the Feed the Future Initiative in 2010 has resulted in a substantial increase in funding. US contributions to the CGIAR Consortium of international agricultural research centres account for 12% of total CGIAR funding, but increases in other donors' contributions has decreased the US share. US agricultural universities attract significant numbers of foreign students, including from developing countries, and US foreign agricultural assistance programmes emphasise building national capacities in agricultural sciences in developing countries.

Agricultural research funding has evolved to better exploit public-private complementarity. Private expenditure on food and agricultural R&D nearly doubled in real terms between 2003 and 2013, while public expenditure declined. As a result, public funding now accounts for less than a quarter of the total. There is evidence that public R&D stimulated greater private R&D by creating opportunities for business, demonstrating complementarity of efforts, but also the importance of maintaining public research capacity. As public and private R&D are not perfect substitutes, the declining role of US public agricultural R&D is not offset by the rise in private R&D. It may result in fewer science and technology breakthroughs over time and risks the long-term sustainability of productivity growth. Moreover, given the global importance of the US system (as described above), this has not only domestic but also international implications.

At the same time, public efforts has increasingly focused on socially important issues like environment, food nutrition and safety, economics and statistics, and community development, while maintaining significant investment in plant and animal systems.

Changes in funding mechanisms for public and private research reinforce the role of the federal government in guiding research efforts. The share of competitive research funding has increased at the expense of research capacity grants to reach half of USDA support for extramural research by 2010. Although the share of competitive funding in USDA is lower than in other federal agencies, this movement raises concerns among researchers as it increases transactions costs. There are also concerns that greater reliance on competitive funding shifts research prioritisation from state to the federal level, as research capacity grants allow state research organisations to set their own priorities. But this could help ensuring coordination towards national objectives. Evidence that US competitive funding of agricultural R&D has higher impact has not yet been demonstrated.

Innovation policy also encourages public-private research collaboration. Most mechanisms are generic, but some are specific to food and agriculture. In the early 1980s, new legislation encouraged government laboratories to increase cooperation with the private sector and allowed them to enter into cooperative R&D agreements with private companies, authorised the patenting of publically funded research; and established the SBIR programme, which requires a minimum percentage of government agency funding to be allocated to small businesses. More recently, the Foundation for Food and Agricultural Research was created as a non-profit, non-government organisation to support joint public-private funding of food and agricultural research. Cooperation awards are also used as well as use-lease mechanisms, by which a company can build a lab within government research facilities.

Strong intellectual property protection has encouraged private investment in R&D. Intellectual Property has long been well protected using a diversity of mechanisms. There is widespread use of patents for transgenic crops, an area attracting private sector investment. As utility patents do not have saved seed or research exemptions, they offer a more stringent form of intellectual property rights than plant variety protection, but may limit further innovation. Companies often apply to both patents and plant variety protection certificates for the same cultivar.

Tax incentives play a growing role in encouraging R&D in private firms, but less so than in some other OECD countries. The federal government offers three tax provisions to encourage private firms to engage in R&D: a deduction from taxable income for research expenses; a tax credit for increasing research activities; and, since 2015, and an exemption for donations to charitable agricultural research organisations. These tax provisions have increased and now account for about a quarter of all support to private R&D. Moreover, they have been made permanent in 2015. Although there are special provisions for start-ups, tax incentives benefit firms already engaged in significant research activities, and income provisions benefit only those who make profit.

Public extension services have responded to a wide range of innovation needs. Extension is integrated with research and education through the land-grant university system. Public extension services provide a wide range of advice on agriculture, conservation, rural development, health, and nutrition, which include knowledge from public and private research and other sources. Through a partnership between federal, state, and local governments, USDA establishes broad priorities for programmes it co-funds, while state and local partners define priorities for cooperative extension. Over time, the share of federal funding has decreased and the consolidation of county programmes has resulted in a reduction of the number of county agents. There is little evidence that is has reduced innovation adoption rates among US farmers, but care must be taken so that farmers continue to have access to advice towards enhancing environmental sustainability and resilience to climate change. Farmers also receive advice from input suppliers and rely on private consultants for independent information.

The agricultural innovation system needs to continuously adapt to new innovation challenges. A significant development is the emergence of stronger linkages between agricultural sciences and other fields, especially biological sciences and information technologies. This has expanded the set of institutions involved in research relevant to agriculture, and the need for coordination and collaboration. Public policy should also encourage multidisciplinary approaches and wider involvement of different stakeholders, which are needed to meet the complex challenges facing food and agriculture.

Building trust in research and innovation remains essential. US farmers, consumers and societies have traditionally been open to innovation as long as there are demonstrable net benefits at no obvious costs, but concerns over the way food is produced are rising. Research needs to demonstrate integrity and responsibility to build trust in society, providing responses to societal and consumer concerns over animal welfare or new technologies such as gene editing for example. Approaches and public involvement in building trust in science may need to evolve.

Strong government leadership in guiding innovation efforts has facilitated adaptation to new challenges. The office of the USDA chief scientist coordinates agriculture-related research across USDA and other federal government agencies with consultation taking place at different levels involving both internal and external stakeholders. USDA participation in the coordination bodies of the national science and technology council helps integrate food and agriculture in the general strategy. Project funding is multiannual, but budget appropriations are decided every year by Congress, which in some cases includes prescriptive budget lines. Competitive allocation of research funding allows federal agencies to better coordinate the research agenda. Integration between food and agricultural research, education and extension facilitates responsiveness to emerging needs.

Government receives advice from the National Academy of Science, which in a 2009 report called for stronger integration of new advances in fundamental biological sciences into federal science agencies to address pressing societal needs, especially for food, environment, energy and health. Stakeholders inform and influence priorities through formal mechanisms such as membership of a national advisory board. In addition research agencies engage public and private stakeholders when planning major programme activities. This process could become more formal to ensure the balance of interests.

Efforts to improve transparency and evaluation will contribute to greater relevance and trust. The comprehensive database on US agricultural research, created in the late 1960s, is an essential tool for planning of research activities. A similar database has been put in place for nutrition research projects. Moreover, the US government supports the sharing of agricultural research-related information at the international level, for example through the Global Open Data for Agriculture and Nutrition (GODAN) project, a G8 initiative launched in 2013.

Government research programmes are evaluated annually and at the end of the five-year cycle, providing useful information for the next cycle. However, evaluation is mainly internal, and more scope could be given in the process to external expertise, including wider reviews of the food and agricultural innovation system. Evidence of widespread adoption of some innovation is well-documented and analysed. Access to long time series and rich information has generated a wealth of evaluation of the impact of research and innovation on sectoral performance. Results indicate high returns on public research (estimates ranging from 20% to 60% with a median of 40%) with these benefits lasting for several decades. These studies also found benefits of public agricultural research were widely shared, not only among farmers but also with consumers in the form of more abundant and lower cost food.

The government has an important role to play in providing systems needed to share information, reduce information gaps to better guide private investment decisions, monitor economic and environmental performance of the sector, identify market and policy failures, and improve policy design, implementation, monitoring and evaluation.

Recommendations to strengthen the food and agricultural innovation system

- Establish a national innovation office to increase coherence and continuity in implementation of the national innovation strategy, as done in other OECD countries with productivity commissions. Pursue efforts to build bridges with other sectors in response to changing global landscape for science and technology, including the emergence of integration of life sciences in other disciplines.
- Strengthen mechanisms to better reflect environmental and societal considerations in agricultural research and facilitate the development of technologies and systems allowing for a better management of natural resources and improved resilience to risks. Integrate food and agriculture in the climate-change strategy, including energy saving promotion and low carbon technology in the sector.
- Maintain public research capacity in food and agriculture, with secure and adequate funding. Evaluate public research infrastructure to upgrade equipment and rationalise costs. Build further complementarity with private R&D and focus on public good aspects. Strengthen assistance to global food and agricultural science and development for agricultural innovation.
- Review the efficiency of different funding mechanisms to ensure higher impact. Consider greater use of mechanisms that incentivise transdisciplinary and system-based approaches, and wider stakeholder involvement that increases relevance.
- Explore further research collaboration opportunities at multilateral level or with non-traditional partners, in particular to deal with global issues.
- Ensure farmers continue to receive advice facilitating sustainable management and adaptation to new pressure, despite reductions in expenditure for public extension services, and have ready access to the newest technologies available to maintain competitive hedge.

- Strengthen support to technical assistance and research projects in agri-environmental policies and use it to better understand issues and needs.

- Continue funding and improving tools for improved monitoring of research investments and results, in collaboration with other countries and organisations, to allow for better impact analysis and review of innovation policy mechanisms and broader reviews of the food and agricultural innovation system. Promote the integration of research data at the international level. Share data and experience of information systems with other countries, as foreseen in the GODAN project and the Global Research Collaboration Platforms (GRCPs) to be developed by a working group on Agricultural Technology Sharing (ATS) led by China to map and analyse the strengths and weaknesses of existing knowledge and information-sharing mechanisms (G20 Communiqué, 2016).

- Develop improved, transparent, and flexible regulatory and information programmes for biotechnology, animal welfare, and climate change to facilitate the public acceptance of innovations in these, and other areas, and the materialisation of their potential benefits.

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Chapter 2

OVERVIEW OF THE FOOD AND AGRICULTURAL SITUATION IN THE UNITED STATES

This chapter outlines the main challenges and opportunities for the US food and agriculture sector, and the drivers of its performance, including innovation. It outlines the contribution of the sector to the economy, and the natural resource base upon which it relies. It identifies the main structural characteristics of primary agricultural and upstream and downstream industries; describes the main food and agriculture outputs and markets; reviews trends in farm and household income performance; and analyses developments in agricultural productivity and sustainability, and their main drivers: innovation, natural resources, climate change, and structural change – which in turn are influenced by a range of policies.

Challenges and opportunities: The need for innovation in food and agriculture

The demand for agricultural products is growing and changing. Rising incomes in the developing world are creating a growing global middle class, which in turn is creating increased global demand for meat and dairy products along with the animal feeds used to produce them. At the same time, a substantial volume of US crop production is going to produce fuel. Each development increases the demand for US agricultural products.

US consumers are turning toward a diet differentiated along several dimensions. They eat more fresh fruits and vegetables, year round, and rely on a sophisticated transportation and marketing network to deliver those products in a timely fashion, even while some households also want more foods produced locally, near their homes. Consumers are increasingly interested in how agricultural products are produced, and attach increasing value to animal welfare, fair trade, environmental stewardship, and nutritional attributes of food products. These developments, which are also occurring in other high income countries, have led to adjustments in global supply chains in which private procurement standards play a major role.

Farmers face a growing set of climate-related challenges in meeting those demands. Climate change is expected to raise growing season temperatures; alter the amount and variability of rainfall; reduce soil moisture; and ease the wider spread of animal and plant pests and diseases. These developments threaten crop yields and pose significant risks for animal production.

Farmers also face the challenge of meeting growing and changing demands for agricultural products while still conserving soil, air, and water resources. While soil losses, aquifer depletion, and nutrient over-applications have been slowed through the application of technologies and the financial support and incentives provided by public policy, increasing commodity demands and climate stresses pose new threats.

Innovation has driven the growth of agricultural productivity in the United States over the last seven decades. The sector's capacity to meet these new demands, while maintaining and improving its record of sustaining natural resources, depends critically on the further development and diffusion of innovations in farm inputs, farm production, food marketing, and public policy.

Past productivity growth has benefited from mechanical innovations in agricultural equipment, and from innovations in how farms and agri-business are organised and how they interact with one another. Further developments along these lines will be crucial. However, investments in science, which have played a primary role in supporting past productivity growth, continue to provide the largest opportunities, and challenges, for meeting future demands for agricultural products.

Developments in science — particularly the integration of the life sciences with physics, engineering, and computational sciences represented as the "New Biology" — provide enormous opportunities for developing the innovations needed to spur continuing productivity growth in agriculture while sustaining resources. However, effective application of scientific developments to the food economy will depend on continuing innovations in public policy, in the form of transparent and well-designed regulations on the testing and commercial introduction of products; communication and statistical reporting that provides comprehensive and trusted information; and programmes to provide financial support for research and conservation.

The place of food and agriculture in the US economy

Production and land use

US agriculture produces a diverse array of commodities from a wide range of soils and climates. It is a market-oriented sector, in which prices respond to market shifts, and producer decisions are responsive to price signals. The farm sector accounts for about half of all land, about 1.5% of total employment, and about 1% of Gross Domestic Product (GDP).

The United States is a large, high-income country with a substantial endowment of agricultural land (Table 2.1). With a total GDP comparable to the European Union, the United States has higher per capita levels of GDP, water resources, and arable land. As in other high-income countries, primary agriculture is a small part of the economy: value added in agriculture amounted to 1% of GDP in 2014, compared to 8% in 1950 (Figure 2.1). The long-term decline in agriculture's share reflects slow growth in domestic food consumption, combined with high growth in agricultural productivity, which reduces the amount of land, capital, and labour required per unit of agricultural production. However, because of the country's large endowment of arable land, agriculture remains a large industry that accounts for a significant share of US exports.

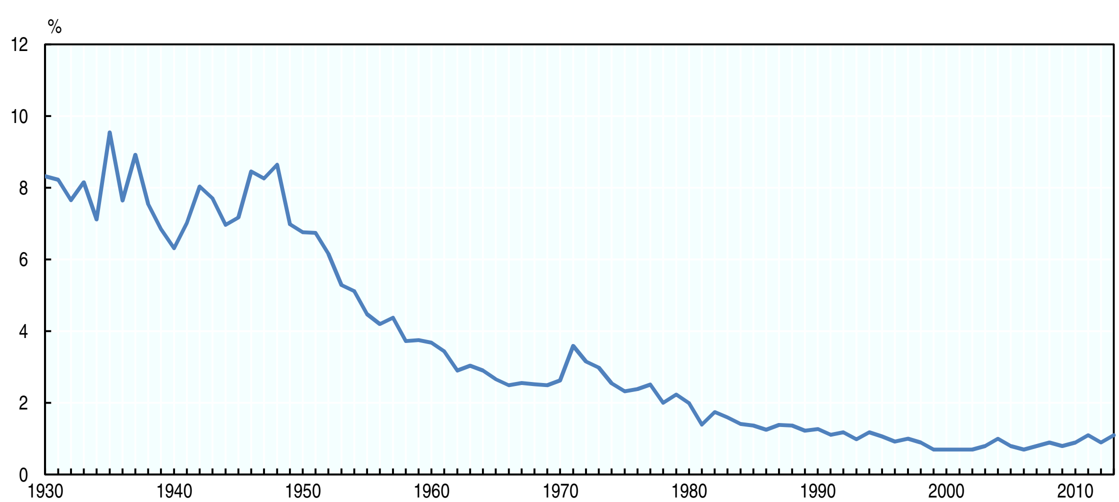
Table 2.1. Contextual indicators, 2014*

	GDP	GDP per capita	Population	Total land area	Agricultural land	Arable land per capita[1]	Freshwater resources[1]	Freshwater resources per capita[1]
Unit	PPP USD billion	PPP USD	Million	'000 km2	'000 ha	Hectares	Billion m³	m³
Year	2014	2014	2014	2013	2013	2012	2013	2013
United States	**17 348**	**54 353**	**319**	**9 147**	**405 437**	**0.49**	**2 818**	**8 914**
(ranking)	*(1)*	*(10)*	*(3)*	*(3)*	*(2)*	*(15)*	*(4)*	*(51)*
Australia	1 095	46 281	23	7 682	396 615	2.07	492	21 272
Brazil	2 974	15 065	199	8 358	278 808	0.37	5 661	28 254
Canada	1 600	45 025	36	9 094	65 251	1.32	2 850	81 071
China	18 015	13 171	1 394	9 425	515 358	0.08	2 813	2 072
EU28	18 758	36 920	508	4 238	186 356	0.26	1 505	4 740
Russian Federation	3 359	22 629	144	16 377	216 840	0.84	4 313	30 056
South Africa	705	13 032	53	1 213	96 841	0.23	45	843
OECD	49 688	39 217	1 264	34 341	1 211 805	0.30	10 466	28 117

* Or latest available year.
PPP: Purchasing Power Parity.
1. World Bank, *World Development Indicators, 2015*. http://data.worldbank.org.

Source: OECD (2015), *Agricultural Policy Monitoring and Evaluation 2015*, http://dx.doi.org/10.1787/agr_pol-2015-en.

Figure 2.1. Agriculture's share of US GDP, 1930-2014



Source: US Department of Commerce (2015), Bureau of Economic Analysis, www.bea.gov/industry.

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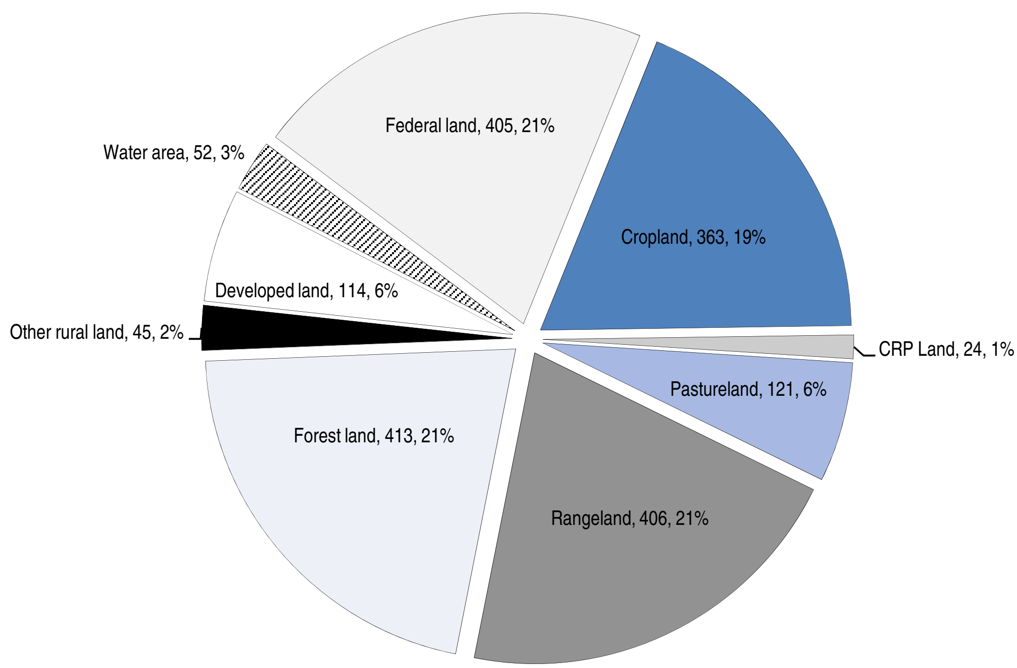
The food system includes agriculture, food processing, wholesaling, retailing, food service, and input suppliers to the farm sector, and the food system combined accounts for about 6% of GDP. Because food retailing and food services are labour intensive industries, the food system accounts for a substantial share of total employment. In 2014, 10.7 million people were employed in food services, including restaurants, many on a part-time basis. Another 6.2 million people were employed in food processing, retail food stores, and farming (including those self-employed in farming). The total, 16.9 million, amounted to 11% of total US employment.

Agriculture uses nearly half of the land area in the United States (Figure 2.2). Twenty-seven per cent of the country's surface area is devoted to pasture and range land (in addition, some federal land is also used for grazing). Cropland accounts for about 19%. The amount of land used for crops has remained remarkably stable in spite of a growing population and spreading suburban development. In 2012, 340 million acres of cropland were used for crops, compared to 331 million acres in 1987 and 383 million in 1982 — the extreme values in a series that extends back to 1945.

Figure 2.2. US surface area by land cover and use, 2012

Millions of acres and percentage of total surface area



CRP: Conservation Reserve Program.

Source: USDA (2015j), Natural Resource Conservation Service, Natural Resource Inventory. www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

StatLink http://dx.doi.org/10.1787/888933408091

California, on the Pacific Coast, is the leading agricultural state, with about 12% of the value of US production, focused on intensive fruit, nut, vegetable, and dairy operations. Eight Midwestern States, with an emphasis on field crops, cattle, dairy, and pigs, together account for 30% of the value of US agricultural production, while five adjoining Great Plains States, with a major focus on field crops and cattle, add another 16%. Six Atlantic Coast states (Florida, Georgia, North Carolina, Virginia, Delaware, and Maryland) specialise in poultry, pigs, and specialty crops, and jointly account for nearly 10% of the value of production.

US agriculture is highly diversified. Total sector cash receipts are split almost evenly between crops and animals/animal products (Table 2.2). In turn, three aggregations — meat animals and their products (cattle and pigs); dairy products and poultry and eggs; and feed and oil crops — each account for about one quarter of cash receipts, while vegetables, melons, fruits, and nuts together account for another one-eighth.

Table 2.2. Cash receipts in the US farm sector, by commodity class, 1955, 1985 and 2014

Percentage of all cash receipts

	1955	1985	2014
Animals and products	54.1	48.6	50.4
Meat animals	28.0	26.9	25.6
Dairy products	14.2	12.5	11.7
Poultry and eggs	10.8	7.8	11.5
Miscellaneous animals, products	0.9	1.4	1.6
Crops	45.9	51.4	49.6
Food grains	6.7	6.2	3.7
Feed crops	8.7	15.5	15.5
Cotton	8.7	2.6	1.8
Oil crops	3.8	8.6	10.3
Tobacco	4.2	1.9	0.4
Vegetables and melons	5.7	6.0	4.5
Fruits and nuts	4.3	4.8	7.1
All other crops	3.7	5.8	6.3

Source: USDA (2015c), Economic Research Service, Farm Income and Wealth Statistics. www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/us-and-state-level-farm-income-and-wealth-statistics.aspx.

Recent years have seen shifts in area planted to different crops in response to changes in commodity prices, particularly as growing ethanol production increased the demand for maize. Some of the increased demand was met through yield increases, but planted maize area rose from 80 million acres (1 acre = 0.404686 ha) in 2000 to 97 million in 2013, before falling back to 88 million acres in 2015. Soybean area also expanded in recent years, to 83 million acres in 2015, and maize and soybeans together accounted for 53% of all area planted to principal field crops in 2015, up from 47% in 2000, according to the annual *Acreage* report produced by the National Agricultural Statistics Service of the US Department of Agriculture (USDA) (USDA/NASS, 2015). Acreage planted to wheat, cotton, and hay — the third, fourth, and fifth largest crops by planted area — fell by nearly 17 million acres over 2000-15.

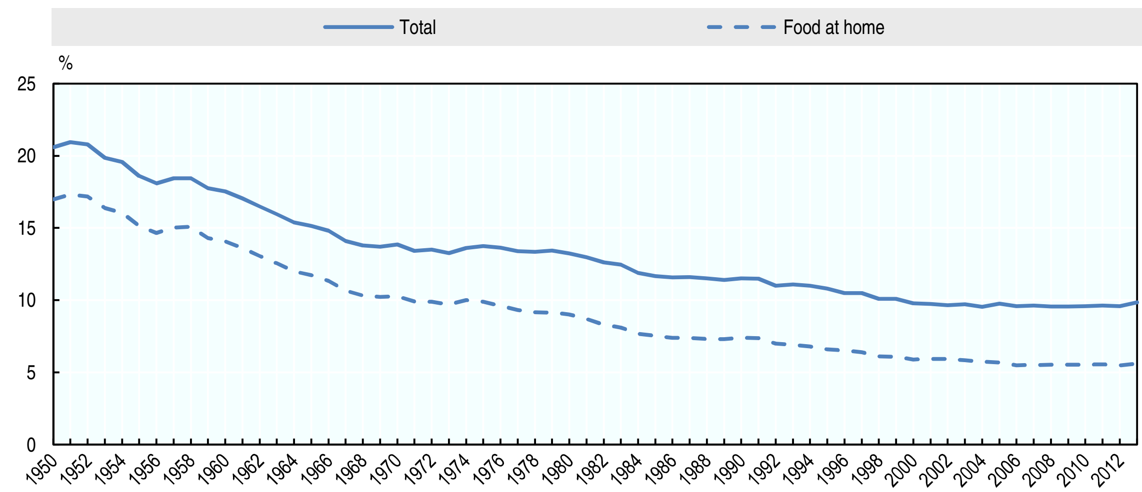
Domestic food consumption

Consumer decisions — about what to eat, whether to eat at or away home, and how to prepare food — play a driving role in retailer and processor strategies and ultimately in agricultural production.

As in other higher-income countries, food spending in the United States accounts for small shares of aggregate income, and changes in income have small effects on per-capita food spending. Recent Economic Research Service (ERS) research finds that food spending by US households is not very responsive to changes in household income and total spending. Specifically, 1.0% increases in total household expenditures are associated with increases of just 0.01 to 0.21%, on average, in expenditures for different major food groups (Okrent and Alston, 2012).

As a result, domestic food consumption is rather insensitive to business cycles, falling little during recessions, but rising little in response to expansions. However, this finding also implies that the share of consumption devoted to food will decline over time as incomes grow. Expenditures on food accounted for over 20% of personal household disposable income in the United States in 1950, but fell to 9.8% by 2013 (Figure 2.3). Over the same period, the share of income devoted to food consumed at home fell even more rapidly, as the share devoted to food consumed away from home rose slightly.

Figure 2.3. US food expenditures as a share of personal disposable income, 1950-2013



Source: USDA (2015d), Economic Research Service, Food expenditures series. www.ers.usda.gov/data-products/food-expenditures.aspx.

StatLink http://dx.doi.org/10.1787/888933408109

In turn, expenditures on farm commodities account for a small share (17.4% in 2013) of consumer expenditures on domestically produced food. Current estimates are produced with methods that cannot be extended before 1993, but it appears that farm shares were substantially higher in the 1960s and 1970s. The long-term declining share of the farm sector in domestic food expenditures follows from three main factors: relatively rapid productivity growth in agriculture, which reduces the agricultural inputs required for any given volume of consumer food products; increased processing of food products, which adds inputs in the processing and retailing sectors; and a shift of consumption to food consumed away from home (food service and restaurants) which adds service inputs to food retailing.

Changes in American diets have led to several important changes in agricultural production. While total per capita meat consumption changed little between 1970 and 2013, the mix changed sharply, toward more poultry, less pork, and substantially less beef. Americans also consumed more fresh fruit and less processed fruit; more processed potatoes; and more fresh green vegetables (USDA/ERS, 2016a).

Food consumption has become more diversified in several important ways. Consumers now spend nearly half of their food dollars on food away from home (Figure 2.3). When they eat at home, they can chose from a wider variety of foods provided through their supermarkets, including products that require very little home preparation time, such as pre-cut fresh fruits and vegetables or pre-cooked meat items (Martinez, 2007). There is widespread and growing interest in food with specific product attributes, such as distinct varieties of fruits, meat from specific pork breeds, or coffee from specific locations.

There is also growing interest among food consumers and retailers in how farm products are produced, and not just in the sensory attributes of the products themselves. The most well-known package of alternative practices, organic agriculture, eschews the use of synthetic chemicals, genetically engineered seeds, and certain animal drugs in production. While the organic sector is still a small part of US agriculture, it has grown rapidly. Three million acres of US cropland and about 255 000 milk cows were certified organic in 2011, up from 1.3 million cropland acres and 49 000 milk cows in 2001 (USDA/ERS, 2016b).

Other examples of differentiation by production practices include eggs that are produced by layers who are not confined in small cages ("cage-free"); pork production using sows that are not confined to gestation crates; grass-fed beef; meat from animals that are raised without antibiotics; products derived from crops that have not been genetically modified ("GMO-free"); and coffee that is produced under "fair trade" standards.

According to USDA's Agricultural Marketing Service, consumers purchased meats and produce directly from farmers at over 8 000 farmer markets in 2014, more than double the number ten years before. Sellers in farmers markets often base their marketing efforts on the practices used to produce products. To choose another example, the Consumers Union conducted a recent survey of 35 grocery store chains, and found that 31 of them offered meat and poultry products that were labelled as raised without antibiotics (Consumer Reports, 2012). Various kinds of animal welfare standards are also being introduced in product marketing.

These are a few examples of a much broader shift to a more diverse array of products. Because most consumers are unable to observe how animals and crops are raised, issues of labelling, certification, and information provision are crucial for marketing these products. The growth in organic production has in part been spurred by an organic certification programme performed by 3rd party certifiers under USDA administration. The Department offers verification services for other claims about production practices, and various private certification services have emerged to provide verification as well.

Food labelling has become a political issue in several states and in the US Congress. Voters in California rejected a ballot initiative that would have required labelling of some foods made from genetically modified plants in 2012, and in 2013 voters in the state of Washington rejected a similar initiative. In 2014, the legislature in the state of Vermont passed an Act requiring such labelling as of 1 July 2016. In late July 2016, a federal law was enacted requiring mandatory labelling of food products made from genetically modified plants, and which will pre-empt the Vermont law. This law will require food manufacturers to provide an on-package disclosure in the form of text, a symbol, or an electronic link, such as a scannable code, that would inform consumers whether a product contained ingredients from genetically modified plants. Restaurants are exempted from labelling requirements, as are products derived from animals whose feeds contained genetically modified crops.

Farm structure

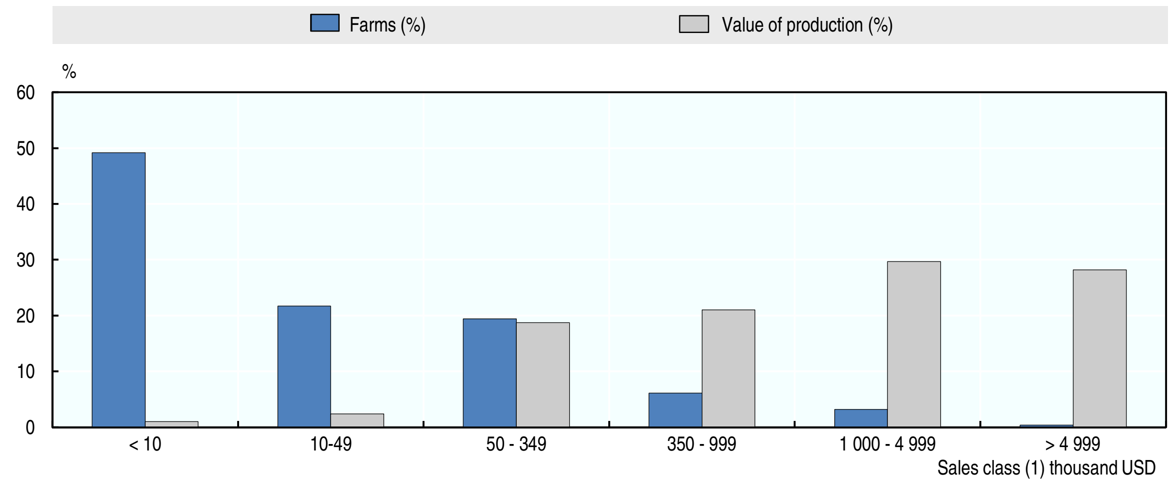
The US farm sector includes an extraordinary range of farms of different sizes. While farms are less diversified, on average, than they were a century ago, most still produce a range of different commodities. Production is shifting to larger farms in most commodities and most states, but even so family farms still dominate the sector.

In US farm statistics, a farm is any place that produces, or normally could produce, at least USD 1 000 of agricultural commodities in a year. The definition, in place since 1974, is not adjusted for inflation. With rising prices for farm commodities, more very small units will be counted as farms, and the statistics do show a growing number of very small farms. The US Department of Agriculture (USDA) reports that there were 2.08 million farms in 2014. Half had sales of less than USD 10 000, and collectively those farms accounted for 1% of agricultural production (Figure 2.4).

The consolidation of farm production in larger operations has been rapid. About 75 000 farms — 3.6% of the total — had sales of USD 1 million or more in 2014, and those farms accounted for 57.9% of the value of US farm production, up from 33% of production in 1996 (Figure 2.5). This comparison adjusts for inflation in farm commodity prices using the Producer Price Index for Farm Products (US Bureau of Labor Statistics), and compares 1996 and 2014 sales using 2014 prices. Most of the shift in production to larger size classes has come at the expense of small commercial farms with USD 50 000-USD 350 000 in sales. Those farms accounted for over one third of total production in 1996, but less than 20% by 2014.

Figure 2.4. The size distribution of US farms, 2014

Percentage of farms or production



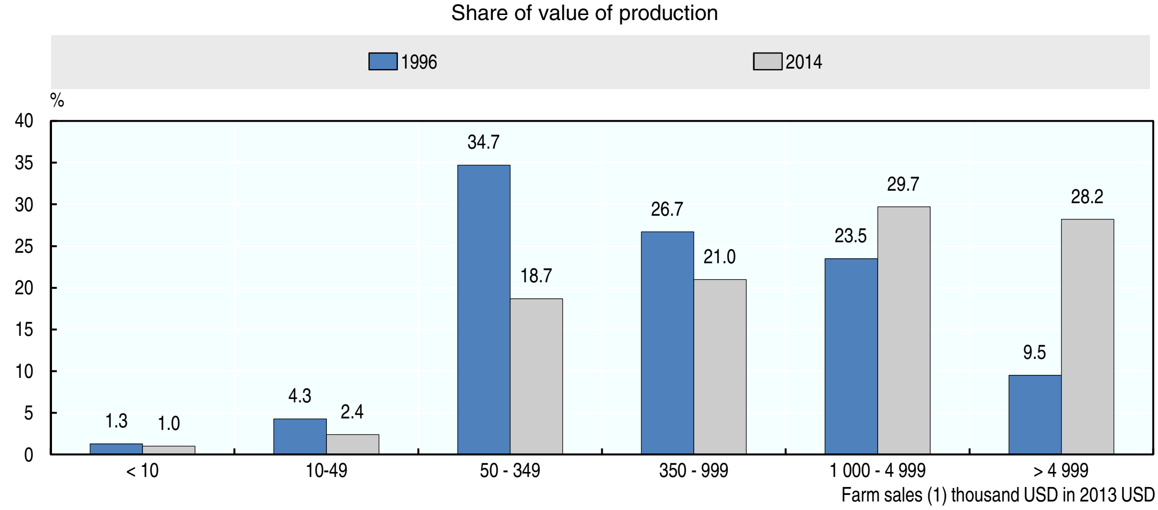
1. Sales are measured by gross cash farm income.

Source: USDA, (2015a), *Agricultural Resource Management Survey (ARMS),* www.ers.usda.gov/data-products/farm-household-income-and-characteristics.aspx.

StatLink http://dx.doi.org/10.1787/888933408114

Figure 2.5. Agricultural production is shifting to larger farms, 1996 and 2014

Share of value of production



1. Sales measured as gross cash farm income.

Source: USDA (2015a), *Agricultural Resource Management Survey (ARMS),* www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/888933408127

With a highly skewed farm size distribution, simple measures of mean size may not be effective for tracking consolidation of land or production. In this case, a midpoint measure can be useful. The midpoint is a type of median, the size of farm at which half of acres (or production) are on larger farms and half are on smaller. Among US crop farms, the midpoint size, measured in acres of cropland, was 600 acres in 1987 — half of all US cropland was on farms with no more than 600 acres of cropland, and half was on farms with no less (MacDonald, Korb, and Hoppe, 2013). By 2012, the midpoint had increased to 1 201 acres.

Production shifted to larger farms in most commodities and in most regions (Table 2.3). For crops, midpoints were calculated based on harvested acres of the crop. For dairy farms, the midpoint is calculated for milk cow inventory (herd size), while for other livestock the midpoint is calculated for annual number of head sold or removed.

In 1987, half of harvested maize area came from farms with at least 200 harvested acres of maize, and half came from farms no more than 200 (Table 2.3). By 2012, the midpoint for maize had grown to 633 acres, as acreage and production shifted to larger farms. Midpoint sizes increased by more than 100% for other major field crops, and also increased, by 100% on average, for most fruit, vegetable, melon and tree nut crops.

Table 2.3. Changes in midpoint enterprise size, selected commodities, 1987 and 2012

Commodity	1987	2012
Field crops	Acres harvested	
Maize	200	633
Soybeans	243	567
Wheat	404	1,005
Cotton	450	970
Vegetables		
Asparagus	160	200
Lettuce	949	1 275
Potatoes	350	1 054
Sweet maize	100	300
Tomatoes	400	930
Tree crops		
Apples	83	179
Almonds	203	547
Oranges	450	1 335
Poultry/livestock	Annual head removed/sold	
Broilers	300 000	680 000
Pigs	1 200	40 000
Fattened cattle	17 532	38 369
	Milk cow herd	
Dairy cows	80	900

For crops, the midpoint size is that at which half of all harvested acres are on larger farms and half are on smaller farms. For dairy cows, half of all cows are in herds larger than the midpoint, and half in smaller. For other livestock, half of all animals sold, or removed under contract, are from farms with more sales, and half with less. The midpoint is the median of the distribution of harvested acres, or livestock, by farm size.

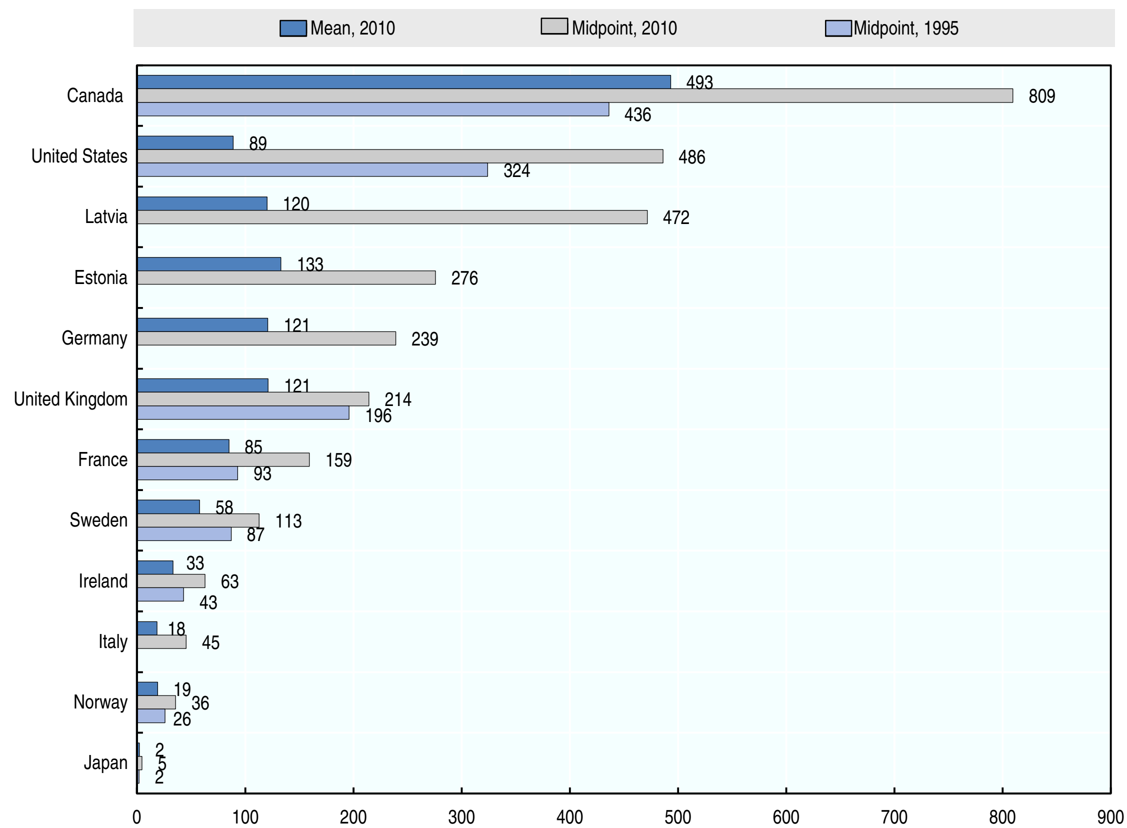
Source: USDA Economic Research Service calculations, from Agriculture Census.

Changes in some livestock sectors were spectacular. In 1987, half of all milk cows were on farms with no more than 80 cows. Twenty-five years later, that midpoint was at 900 cows. The change in pigs was even more dramatic as each industry underwent wide-ranging and comprehensive set of structural changes. Midpoint enterprise sizes for broilers and for fed cattle more than doubled.

Cropland is also consolidating into larger farms in other OECD countries, but the pace of consolidation varies widely. In a comparison of 12 selected OECD countries, the midpoint size of a crop farm was at least 60% greater than the mean size in each, indicating that farm sizes tend to be skewed in all (Figure 2.6). The midpoint crop farm size ranges widely across countries, from 5 hectares of cropland in Japan and 36 in Norway (the small end) to 486 in the United States and 809 in Canada. Temporal comparisons could be provided for eight countries (Canada, the United States, Japan, France, Norway, the United Kingdom, Ireland, and Sweden) for 1995-2010 (Figure 2.6). Midpoint farm sizes increased in each country, and midpoints increased more rapidly than means in each.

Figure 2.6. Farm size in selected OECD countries, 1995 and 2010

Crop farms, ha of cropland



Source: Bokusheva and Kimura (2016). http://dx.doi.org/10.1787/5jlv81sclr35-en.

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There is strong evidence of a link between structural change and productivity growth in the US dairy and pig sectors. In dairy, Mosheim and Lovell (2009) identified substantial scale economies, with unit costs falling sharply through herd sizes of 500 head, and then falling steadily, at a more modest rate throughout the range of herd sizes in their dataset in 2000. Since then, US dairy production has continued to shift to farms with 2 000 or more head, and MacDonald, Cessna, and Mosheim (2016) estimate that the industry's structural change toward larger operations reduced industry-average costs by 19% between 1998 and 2012. In the pig sector, McBride and Key (2013) show that there were significant unexploited economies of scale in 1992, and that in subsequent years industry-average costs fell as farms expanded to realise scale economies, and as continuing innovations in breeding, housing, and feeding reduced costs for all farms. By 2009, the economies of scale in the industry had largely been fully exploited, so that further increases in farm size are not expected to reduce costs. In broilers, there was a more gradual shift to larger operations (Table 2.3), and MacDonald and Wang (2011) identify a small advantage to larger farms from scale economies, consistent with the observed gradual shifts.

The estimation of scale economies and associated size advantages is more technically challenging in crops, because farms usually produce multiple outputs, output decisions are interrelated (via rotation decisions), and generally unobservable weather and soil features play important roles in outcomes. Furthermore, since most farms in the United States remain family-run businesses of relatively small size compared to other businesses, production scale economies are unlikely to be nearly as extensive as they are in some nonfarm industries. Nevertheless, crop production has been shifting to larger farms, and larger field crop, fruit, and vegetable farms appear to realise lower per-acre capital and labour costs than smaller farms over the range of observed farm sizes in the United States (MacDonald, Korb, and Hoppe, 2013).

Technological changes, which allow farmers and farm families to manage more acres, are an important force driving farm consolidation in crop production (MacDonald, Korb, and Hoppe, 2013). Specifically, larger and faster pieces of equipment allow farmers to complete field tasks in less time. Developments in seeds, in chemicals, and in information technology also appear to reduce the hours required for certain tasks. In agriculture, which is still dominated by family farms, reductions in the family hours required for specific field operations can be used to manage larger operations. The value of these labour-saving innovations is conditional on land features. They are most effective in regions with large, flat, contiguous fields. Hence the pace of consolidation differs across States and regions in the United States.

US farms have become much more specialised, although most still combine several agricultural commodities. In the early 20th century, most of them kept a variety of livestock, and they raised feed crops for their animals as well as cash crops for sale. As late as 1960, more than half of US farms grew maize, largely in support of pig, cattle, chicken, or dairy production. By 2012, only one in six farms grew maize. Sixty per cent of those farms raised no livestock, and those that did raise livestock often purchased most of their feed.

The separation of crop production and livestock feeding led to geographic shifts in each sector, as feed grain production concentrated in the Midwest while livestock production shifted toward the South and West (MacDonald, Korb, and Hoppe, 2013). In turn, the geographic movement of commodity production to the regions that were most appropriate contributed to increasing crop yields (Beddow and Pardey, 2015).

Despite the shifts to larger operations, most US agricultural production is carried out on family farms, and most large farms are family farms. ERS defines a family farm as one on which the principal operator, and people related to the principal operator by blood or marriage, own more than half of the farm business. Under this definition, family farms accounted for 99% of all US farms and 90% of farm production (Hoppe and MacDonald, 2015).

Nonfamily farms include farms whose principal operator is a manager hired by the owners to operate the farm; partnerships of unrelated people who jointly operate the farm; and farms operated by large publically-held corporations. Most nonfamily farm production does not come from large corporations, but instead comes from partnerships among unrelated people, who sometimes organise themselves into small tightly-held corporations (Hoppe, Korb, and Banker, 2008).

Agribusiness structure

US farms operate in a food system of processors, retailers, and input providers. Most are large corporations, and few directly operate farms — there is little vertical integration between agriculture and other parts of the food system. However, farms are often tightly linked with other firms in the food system through various types of contractual relationships. Some agri-food firms have been sources of innovation in coordinating production, developing new products, and facilitating the spread of production technologies and practices.

The tightest and most extensive system of contractual control is in broiler chicken production, where firms own processing plants, feed mills, and hatcheries, and contract with farmers to raise broilers for them. Almost all broilers are raised under production contracts; the firms provide farmers with chicks and feed, and provide specific guidelines for equipment and housing requirements and production practices. The pig and turkey sectors are not quite as tightly controlled, but are still dominated by contract production. In other commodities, farmers may use contracts with buyers that tie prices to commodity attributes, and they may have longstanding but less formal ties to specific buyers.

Large retailers affect agricultural production by setting procurement standards. The retailers usually work through processors or other intermediaries, rather than contract directly with farmers, but the requirements that they set — for attributes of products and production processes — are conveyed back to farms through the intermediaries, with third-party certification organisations involved as well.

US farmers also use contracts and leases for many input requirements. Over 60% of US cropland is rented, usually from owners who are not farmers. Farmers also often contract with custom providers of agricultural services, and they often lease equipment. Some crop production arrangements cover seed and chemical purchases, and outlets for the resulting crop, in one package.

Although farms are getting larger, almost all agricultural commodities still feature many producers: agricultural production is not concentrated. The same cannot be said for sellers of farm inputs such as seed, chemicals, and equipment. Nor does it hold for the buying side — the elevators, processors, packers, and retailers who purchase agricultural commodities. The number of highly concentrated agricultural markets has increased greatly. In particular, monopsony (buyer) power matters in some markets.

Processing industries that buy farm commodities directly from farmers often have just a few major producers, and concentration in those industries has risen over time as firms have become larger and fewer (Table 2.4). Similarly, concentration in input industries — like seeds and agricultural chemicals, and in some agricultural transportation services — is high and rising. The issue of concentration and competition in meatpacking has attracted considerable attention, fuelled by the dramatic increase in concentration in beef in the 1980s and 1990s. However, concentration is not increasing in all of agribusiness — concentration has fallen quite sharply in ethanol as many new firms entered the industry.

Food retailing has also undergone significant change in the last 25 years. The four largest grocery retail chains accounted for 36% of grocery store sales in 2013, up from 17% in 1992. Supermarkets have grown much larger, and provide a much wider range of products. Non-traditional retailers, including mass merchandisers, supercentres, club warehouse stores and dollar stores, have increased their food offerings since the mid-1990s, and now account for a significant share of all retail food sales in the United States (Leibtag, Barker, and Dutko, 2010). Technology and scale are at the heart of the growth of these stores (Basker, 2007). They have developed innovations in logistics, distribution, and inventory control that allow them to realise lower costs than traditional single-store and chain retailers; the firms combined these technological innovations with a location strategy of placing stores in high-volume sites near highways, allowing the firms to realise economies of scale in distribution and retailing. The entry of these stores, and their replacement of traditional retail stores, accounted for almost all growth in labour productivity in the US retail sector during their expansion in the 1990s (Foster, Haltiwanger, and Krizan, 2006). Between 1994 and 2014, labour productivity in retail trade rose by 3% per year, according to the US Bureau of Labor Statistics, compared to growth of 0.6% per year in traditional supermarkets.

Non-traditional retailers offer lower prices to consumers, and their presence places downward pressure on other retailers' prices. Basker (2007) reports that prices at Walmart, the largest non-traditional retailer, ranged from 8 to 27% lower than those at traditional supermarkets, depending on the market and products evaluated. Some of those differences may reflect differences in package sizes, but Leibtag, Barker, and Dutko (2010) reported that prices at non-traditional retailers were 7.5% lower, on average, than prices at traditional supermarkets, when comparing identical products. Lower income households are more likely to shop at Walmart and other non-traditional retailers than higher income households, so the price differences offer a larger boost in real incomes to lower-income households.

Sales growth at non-traditional formats have slowed in recent years, as non-food retail sales have shifted to internet outlets, as traditional supermarket chains have adapted, and as non-traditional format food sales have reached maturity. Labour productivity growth in retail trade slowed, to 1.8% annually in 2004-2014 from 4.2% annually in 1994-2004. It remains to be seen whether food retailers will find a new productivity-enhancing set of innovations, or whether the expansion of non-traditional formats represented a one-time improvement to retail productivity concentrated in the 1990s and early 2000s.

Table 2.4. Selected four-firm concentration ratios in US agribusiness

Largest four firms' share of	Beginning year	Ending year
Seed shipments	Year=2000	Year=2007
Maize seed	60	72
Cotton seed	95	95
Soybean seed	51	55
	Year=1980	Year=2007
Railroad grain shipments	53	84
Grain exports	Year=1998	Year=2009
Maize exports	70	80
Wheat exports	47	65
Soybean exports	62	66
Manufacturing shipments	Year=1977	Year=2012
Fluid milk processing	18	46
Flour milling	33	50
Wet maize milling	63	86
Soybean processing	54	79
Rice milling	51	47
Cane sugar refining	63	95
Beet sugar	67	78
Nitrogenous fertiliser manufacturing	34	69
Phosphate fertiliser manufacturing	35	88
Pesticide manufacturing	44	57
Farm machinery	46	61
Livestock procurement	Year=1980	Year=2011
Steer and heifer slaughter	36	84
Pig slaughter	34	64
	Year=1995	Year=2011
Broiler processing	50	52
Turkey processing	41	55

Table reports share of the four largest firms in each activity.

Sources: Seed shipments: Professor Kyle Steigert, University of Wisconsin; Railroad grain: USDA, Agricultural Marketing Service. *Study of Rural Transportation Issues*. April, 2010; Grain exports and livestock procurement: USDA Grain Inspection, Packers and Stockyards Administration; Manufacturing shipments: US Census Bureau.

Farmer-owned cooperatives play a major role in the marketing of farm commodities and the purchase of farm inputs. Cooperatives market farm products on behalf of members, and sometimes process products as well; in each function, cooperatives can help offset the market power held by private processors in some markets. Farm supply cooperatives acquire farm inputs — primarily crop protectants, feed, fertiliser, petroleum, and seed, but also building materials, hardware, and machinery. Service cooperatives provide services such as drying, shipping, storage, or grinding. Cooperatives may also diversify into non-farm businesses, like grocery or gasoline retailing.

In 2014, there were 2 106 farm cooperatives, which in the aggregate recorded USD 147.7 billion in product sales (net of sales between cooperatives), with dairy and grain and oilseed sales accounting for 75% of the total (Table 2.5). Cooperatives also purchased USD 92.6 billion in farm inputs, with petroleum accounting for 42% and fertiliser and feed for another 32%.

Table 2.5. US farm cooperatives by activity, 2000-14

	2000	2005	2010	2014
Marketing cooperatives (number)	1 888	1 586	1 238	1 114
Volume of sales (billion USD)	80.5	80.0	103.9	147.7
Dairy	25.8	31.7	34.3	52.4
Grain/oilseed	22.8	24.0	41.0	58.8
Fruit/vegetable	10.2	7.2	7.7	8.4
Sugar & sugar products	2.7	4.2	5.0	7.8
Farm supply cooperatives (number)	1 293	1 166	916	875
Volume of sales (billion USD)	34.7	38.1	63.8	92.6
Petroleum	11.2	14.4	24.5	39.2
Fertiliser	7.3	6.7	11.1	16.3
Crop protectants	4.0	3.8	8.1	11.5
Feed	6.6	7.0	10.8	13.7
Seed	1.4	2.1	4.3	5.8

Source: USDA (2016a), Rural Development, Cooperative Programs. www.rd.usda.gov/programs-services/all-programs/cooperative-programs.

Some cooperatives have grown quite large. Thirty had more than USD 1 billion in volume in 2014, and they accounted for more than half of total cooperative sales and purchase volume. However, while size can generate scale economies in some functions, large cooperatives frequently contain highly diverse memberships, and goal conflicts among members can hamper performance. Some cooperatives provide specialised services to small numbers of like members — such as veterinary services or feed purchasing services shared across a few relatively large dairy farms.

Farm sector and farm household financial performance

Policymakers, input providers, and farm groups use farm sector income measures to track changes in the financial performance of the farm sector. Net farm income — the most closely tracked indicator — grew to reach record levels in 2013, but has declined sharply since then as commodity prices have declined. Because farm operator households are a highly diverse group, often with multiple sources of income, USDA farm accounts also measure and track changes in the income accruing to farm households.

Net farm income — the return to farm operators for their land, labour, and management after payment of expenses — can fluctuate sharply from year to year, depending on movements in input and commodity prices and on the support provided through government policies (Figure 2.7).

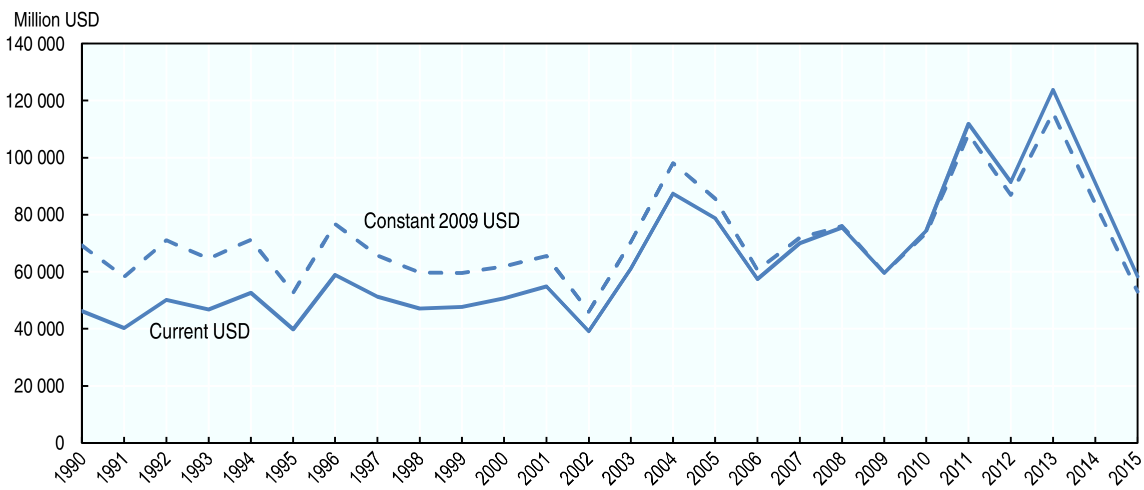
Net farm income averaged USD 81.1 billion per year in 2004-2015, 27% higher than its 1990-2003 average (in inflation-adjusted terms). Net farm income fell by 20% during the global recession in 2009, compared to 2008, but recovered quickly in 2010. It reached a record level of USD 123.7 billion in 2013, but ERS forecasts that it will fall to USD 54.8 billion in 2016, after declining to USD 56.4 billion in 2015.

Commodity price movements drive recent changes in net farm income (Figure 2.8). Grain prices rose by 150% between 2005 and 2008, fell quite sharply in 2009, and have fluctuated widely since then. Prices for slaughter livestock have risen considerably since 2009, but remained at or below their 1990 values until then. The decline in 2015 follows from commodity price declines in all sectors, starting with crops early in the year and spreading through the year to poultry, swine, dairy, and cattle. The volatility in commodity prices has influenced changes in farm policy, toward greater reliance on risk management.

Purchases of new farm equipment move in line with increases in net farm income, increasing during income expansions and falling off during declines. Since new technology is often embodied in new equipment, the diffusion of innovations is affected by changes in income.

ERS tracks household income for the principal operators of family farms (farms may have multiple operators, and ERS asks survey respondents to select a principal operator). Household income provides a more direct measure of the well-being of farm families.

Figure 2.7. Net farm income, 1990-2015

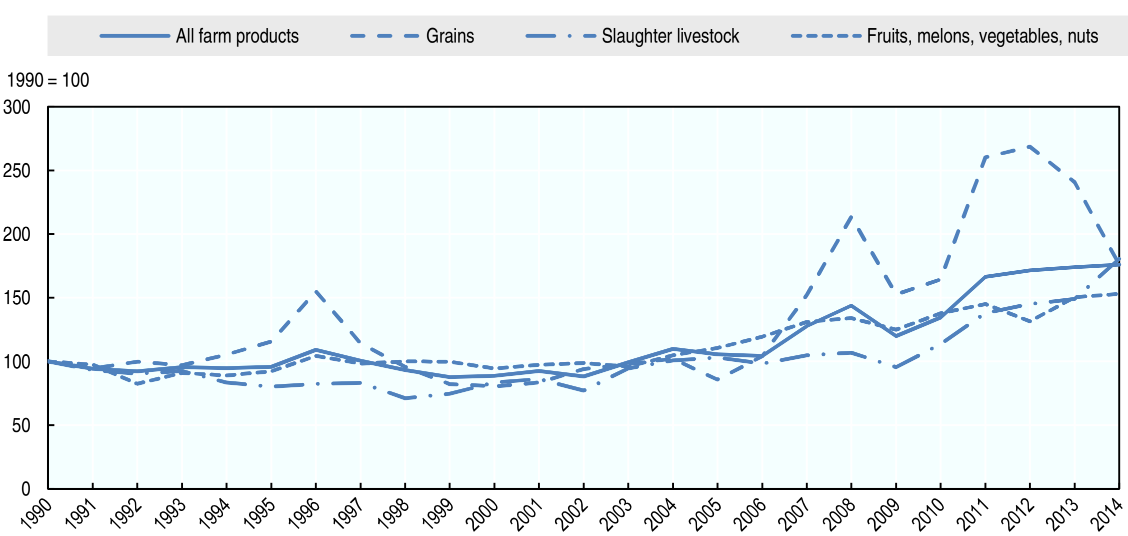


2015 is ERS forecast as of August 2015. Constant USD estimates use GDP chain-type deflator.

Source: USDA (2015c), Economic Research Service, Farm Income and Wealth Statistics. www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/us-and-state-level-farm-income-and-wealth-statistics.aspx.

StatLink http://dx.doi.org/10.1787/888933408144

Figure 2.8. Price trends for farm products, 1990-2014



Source: US Bureau of Labour Statistics (2015), Producer Price Indexes annual. www.bls.gov/ppi/data.htm.

StatLink http://dx.doi.org/10.1787/888933408151

Table 2.6. Farm operator household income, by farm type, 2014

	Share of all		Median household income		Median household wealth
	Farms	Output	From all sources	From farming	
	Percentage		USD		
Small farms (Sales<USD 350 000)					
Operator is retired from farming	13.6	1.2	64 273	4 222	807 000
Primary occupation is non-farming	45.4	5.4	95 120	-4 000	782 000
Primary occupation is farming					
Sales<USD 150 000	25.3	5.8	60 059	-2 250	779 561
Sales of USD 150 000-USD 349 999	5.3	9.4	108 173	51 014	1 570 755
Midsize farms (USD 350 000-USD 999 000)	6.0	20.6	185 306	115 339	2 185 542
Large-scale farms					
USD 1 000 000-USD 4 999 999 in sales	3.0	27.2	368 304	271 522	3 472 740
USD 5 000 000 of more in sales	0.3	19.9	1 183 148	957 301	6 493 950
All family farms	98.9	89.6	80 620	-1 765	872 637

Source: USDA (2015a), Agricultural Resource Management Survey (ARMS) Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

The median household income for principal operators of family farms was USD 80 620 in 2014 (Table 2.6), well above that for all US households (USD 53 657). Because US farms and farm households are highly diverse, ERS has created a farm typology based on farm sales, the primary occupation of the farm principal operators, and whether the operation is a family or non-family operation. ERS reports median household income for primary operators in each class of family farm.

Three small-farm categories (operators who are retired from farming; those with a non-farm primary occupation; and operators for whom farming is a primary occupation and with farm sales of less than USD 150 000) account for 84% of farms but 12.4% of production (Table 2.6). Most of those households, because they do relatively little farming, realise negative net income from farming, and support themselves with off-farm income. Nonetheless, median household incomes in those classes match or exceed median income for the all US households.

Households in the other four classes, which represent just over 300 000 farms (14.6% of all farms), earn larger household incomes on average, with much or most deriving from farm activities (Table 2.6). Their household incomes are much more sensitive to developments in the agricultural economy, although note that most also derive substantial income from off-farm activities, and therefore have some cushion against adverse farm developments.

Average household incomes in the broader US economy exceeded average farm sector household incomes until the 1970s, and in the 1930s and 1940s the farm sector included a significant share of the population living in poverty (Gardner, 2002). But average farm sector household incomes grew more rapidly than those in the overall economy, and now considerably exceed the average for the United States. Operators of commercial farms earn household incomes that are in line with owners of other small-to-midsize businesses in the US economy, which is an important factor in attracting talented people to the industry, and in retaining them.

Agricultural trade

Agricultural exports have been important to the United States since the country's beginning, and global grain markets played a significant role in agriculture's westward expansion in the 19th century. In recent decades, the composition of US agricultural exports have shifted away from bulk grain and oilseed commodities and toward fruits, vegetables, and meat and dairy products.

International trade does not play as important a role in the US economy as it does for some countries, such as Canada, China, or Russia (Figure 2.9). However, imports and exports account for growing shares of US GDP, and the country is far more exposed to trade than it was 30 years ago, when trade exposure (exports plus imports as a share of GDP) was less than 40% of what it is today.

Agriculture has historically accounted for an outsize portion of all US trade. Agricultural exports — including semi-processed and processed food products as well as raw commodities — accounted for nearly 11% of all US exports in 2014 (Figure 2.10). Agricultural exports accounted for 19% of all US exports in 1980; the share later declined as other US industries became more trade-oriented, and reached 7% of US exports in 2000, but has risen since then. The value of agricultural exports has risen quite sharply since 2005, and reached USD 150.5 billion in 2014; with agricultural imports at USD 111.7 billion in 2014, the agricultural trade balance stood at USD 38.8 billion.

The steady improvements in agricultural productivity since the 1940s have been a major reason for the positive trade balance in agricultural products. High agricultural productivity means lower unit costs of production, which improves competitiveness in international markets.

The composition of US agricultural trade has changed sharply since the 1980s (Figure 2.11). In 1980, most US agricultural exports were bulk commodities, with a heavy concentration in maize, wheat, soybeans, and cotton. But, especially over the last two decades, exports of tree nuts and fresh and processed fruits and vegetables have grown rapidly.

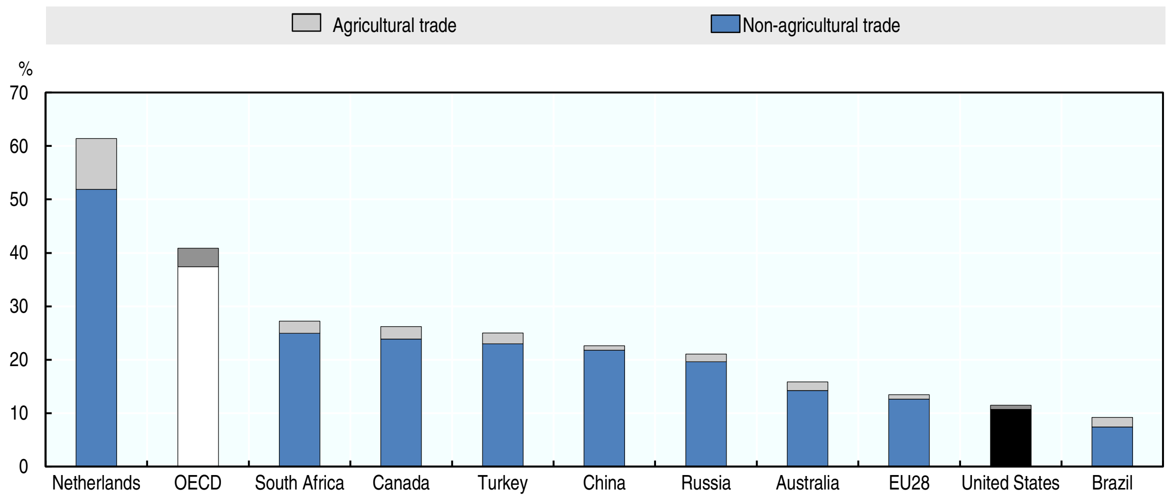
Animal product exports have also become important elements of US trade: dairy product exports increased more than five-fold, pork and pork product exports rose by more than fourfold, while exports of beef and poultry products also grew markedly over the last two decades. At the same time, export values for maize, cotton and wheat declined, and among major field crops only soybeans saw large increases in exports. Of course, maize and soybeans were exported indirectly as feed for animal products that saw large increases in exports.

The geographic focus of US exports has also changed (Figure 2.12). In 1990, Japan and the European Union (EU) were the two largest destinations, and together accounted for nearly 40% of US agricultural exports. By 2014, just over 17% of agricultural exports went to those destinations, while exports to China and North America (Canada and Mexico) accounted for 43% of exports, up from 19% in 1990.

Canada, Mexico, and the European Union accounted for about half of US agricultural imports in 1990 and 2014, but import shares were reallocated among them during the period, with Canada and Mexico accounting for sharply growing import shares. US agricultural imports include cattle and beef products, wines and malt beverages, and tropical products like coffee, cocoa, and bananas.

Figure 2.9. Exposure to trade, 2014

Trade (average of imports and exports) as a percentage of GDP



Source: OECD (2015), System of National Accounts, http://stats.oecd.org and UN COMTRADE (2015), UN http://comtrade.un.org.

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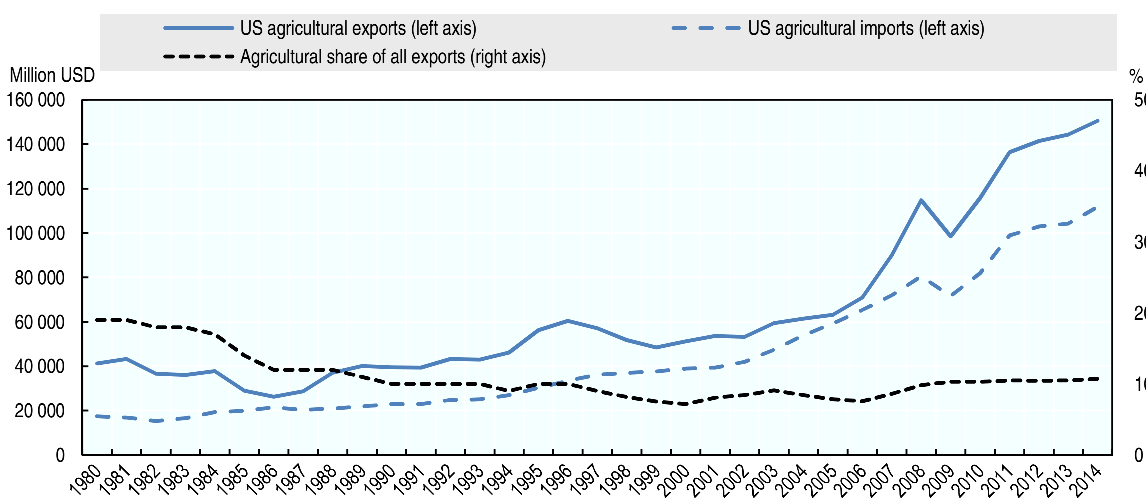
Figure 2.10. US agricultural trade, 1980-2014



Source: US Department of Commerce (2015), Bureau of Economic Analysis. www.bea.gov/international/index.htm#trade.

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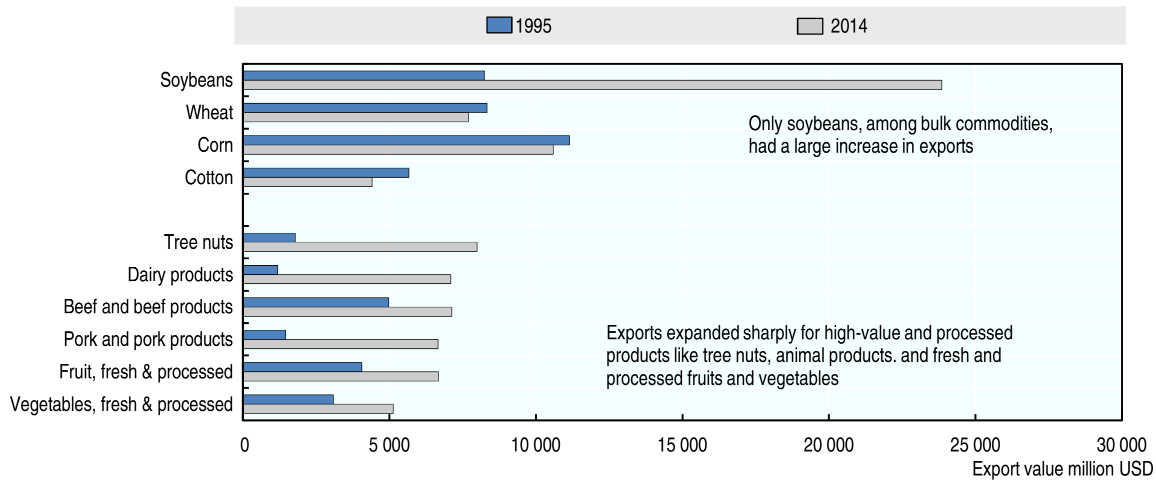
Figure 2.11. Changes in the composition of US agricultural exports, 1995 and 2014



Source: US Department of Commerce (2015), Bureau of Economic Analysis. www.bea.gov/international/index.htm#trade.

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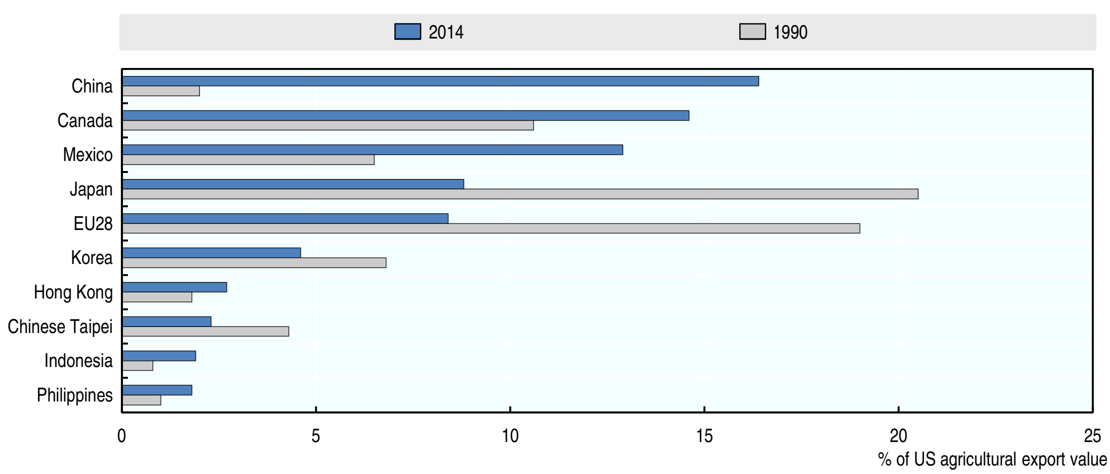
Figure 2.12. The ten primary destinations for US agricultural exports, 1990 and 2014



Source: USDA (2015f), Foreign Agricultural Trade of the United States. www.fas.usda.gov/regions.

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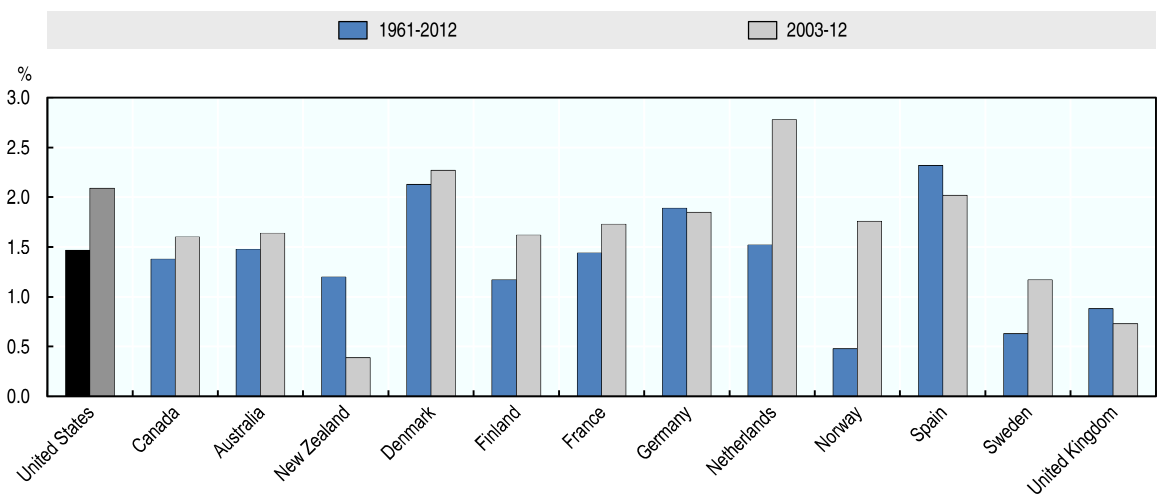
Agricultural productivity

Trends in productivity growth

Agricultural productivity has grown steadily since at least the 1940s. The country has been able to increase total agricultural output by 169% between 1948 and 2013, while reducing the amount of land and labour devoted to agriculture. That growth has come largely through the application of a series of innovations in crop and livestock breeding, nutrient use and pest management, farm practices, and farm equipment and structures, most of them developed from investments in scientific research.[1]

US agricultural productivity has experienced sustained high rates of growth for decades. Using estimates from the ERS International Agricultural Productivity accounts, total factor productivity (TFP) growth in the United States averaged 2.10% per year over 2003-12, and 1.47% per year over the longer period, 1961-2012 (Figure 2.13). The US performance places it among the OECD leaders.

Figure 2.13. Annual agricultural TFP growth rates for selected OECD countries, 1961-2012 and 2003-12



Source: USDA (2015e), Economic Research Service, International Agricultural Productivity: www.ers.usda.gov/data-products/international-agricultural-productivity.aspx.

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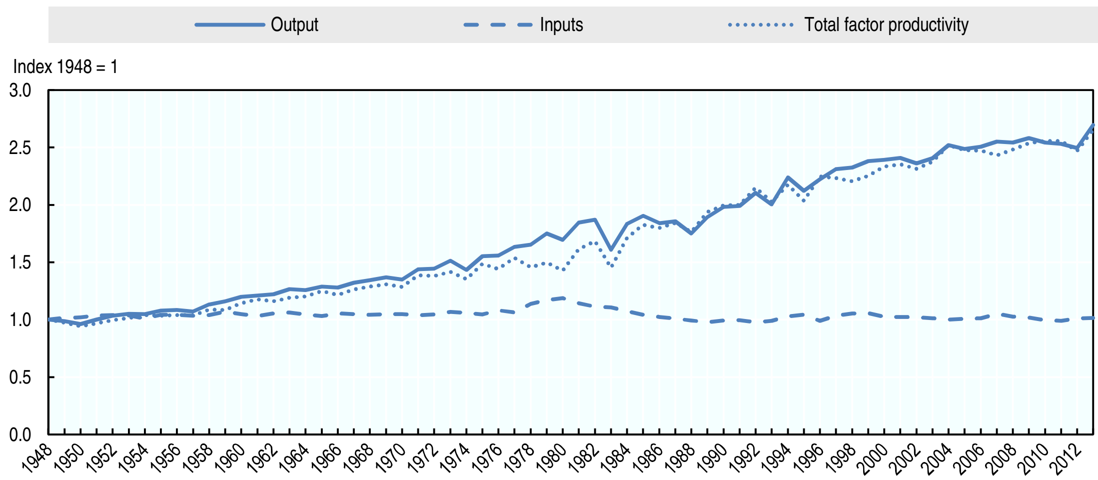
The international TFP comparisons are hampered by data limitations. In particular, they only crudely account for certain important inputs, like pesticides and contract services. ERS produces a more comprehensive set of domestic productivity accounts for US agriculture, covering 1948-2013. This series explicitly accounts for pesticides and contract services, and also quality-adjusts land, chemical, and labour input indexes for changes in factor attributes, while the capital stock index is adjusted for changes in composition over time.

Using the domestic productivity accounts, agricultural TFP grew at an average annual rate of 1.48% per year between 1948 and 2013 (Figure 2.14), and at a rate of 1.45% per year over 1961-2012 (the years reported for the international accounts above). There was essentially no growth in total inputs over the longer period, (although the composition of inputs changed), so TFP growth accounted for all of the growth in agricultural output. This is a distinctive feature of agriculture, because output growth in most other industries in the US economy is driven largely by expanded use of capital, labour, energy, and materials inputs.

Figure 2.14. US agricultural productivity growth, 1948-2013



Source: USDA (2015i), Economic Research Service, Agricultural Productivity Accounts. www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx.

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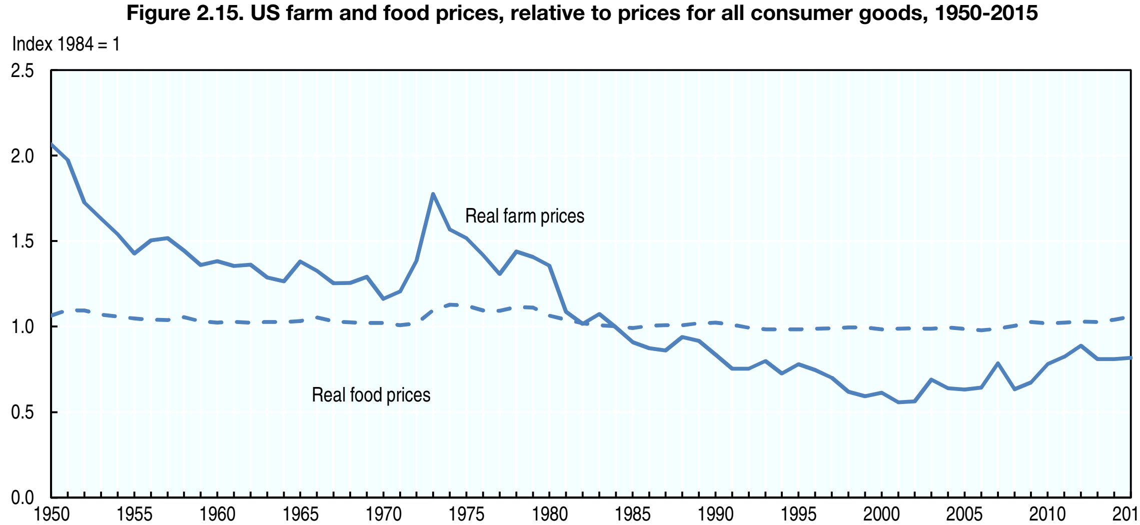
Figure 2.15. US farm and food prices, relative to prices for all consumer goods, 1950-2015



Source: US Bureau of Labor Statistics (2016), Producer Price Index for farm products deflated by Consumer Price Index for food products, each deflated Consumer Price Index for all items. www.bls.gov/ppi/data.htm.

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Productivity growth rates in agriculture are high when compared to the rest of the US economy. For example, Jorgenson, Ho, and Stiroh (2005) calculated TFP measures for 44 industry sectors over 1977-2000. Agriculture had the fourth highest TFP growth rate over that period, and retains its high ranking in a separate comparison of 1947-2012 (Jorgenson, Ho, and Samuels, 2015).

High agricultural productivity growth contributed to generally falling prices for agricultural commodities, relative to prices for consumer products (Figure 2.15); the relative decline was interrupted twice, in the 1970s and in 2001-11, by sharp increases in commodity demand. However, food prices did not fall during the long decline in real farm prices, compared to other consumer products: instead, rapid productivity growth in agriculture just offset slow productivity growth and added services in the rest of the food system to keep food prices rising at the same pace as consumer prices.

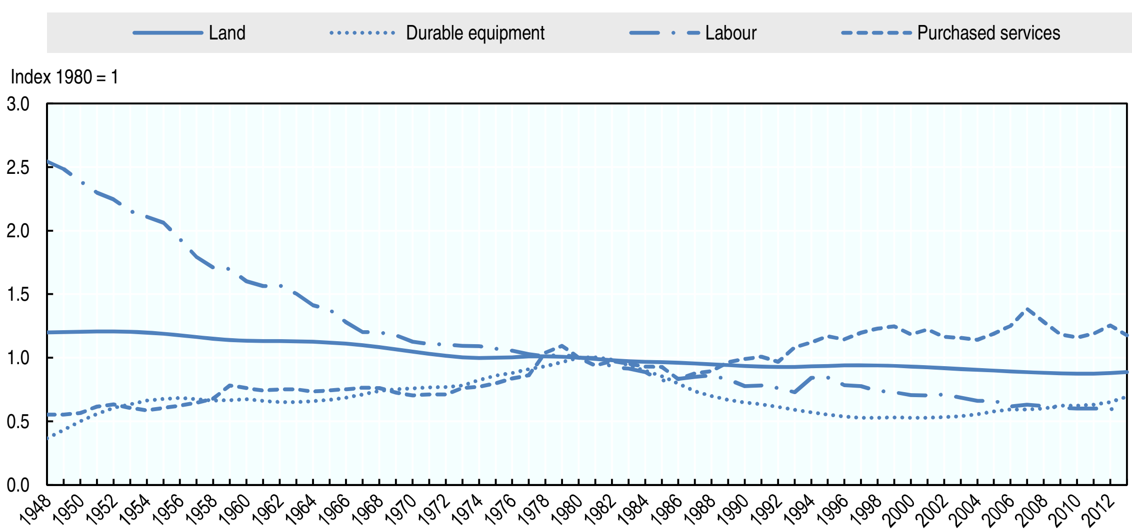
Productivity growth in agriculture constrains food prices, but that effect is modest because farm commodities account for a small share of retail food costs. A major effect of agricultural productivity growth has been to free resources — of labour, land, and capital that would have been needed to produce food — for use elsewhere in the economy.

Productivity growth and input use

There were significant changes in the composition of agricultural inputs over 1948-2013. The amount of labour used in agriculture dropped by about 75% over 1948-2013, even in an index that is adjusted for improvements in education (Figure 2.16). Similarly, the aggregate land input to US agriculture declined steadily, largely because of declines in pasture and rangeland. Between 1948 and 1980, the sector added durable equipment, but that input also declined sharply over 1980-1998, and by 2013 the stock of durable equipment capital still had not returned to its 1980 value.

One reason for the post-1980 decline in durable equipment stocks is a change in farm operator practices, toward growing reliance on purchased services, often in the form of leased capital equipment and the use of custom service providers. These shifts represent organisation innovations that allowed farmers to limit the risks associated with large investments in fixed capital, while in many cases allowing for more intensive use of the equipment.

Figure 2.16. Trends in selected agricultural inputs, 1948-2013



Source: USDA (2015h), National Agricultural Statistics Service, Economic Research Service. www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

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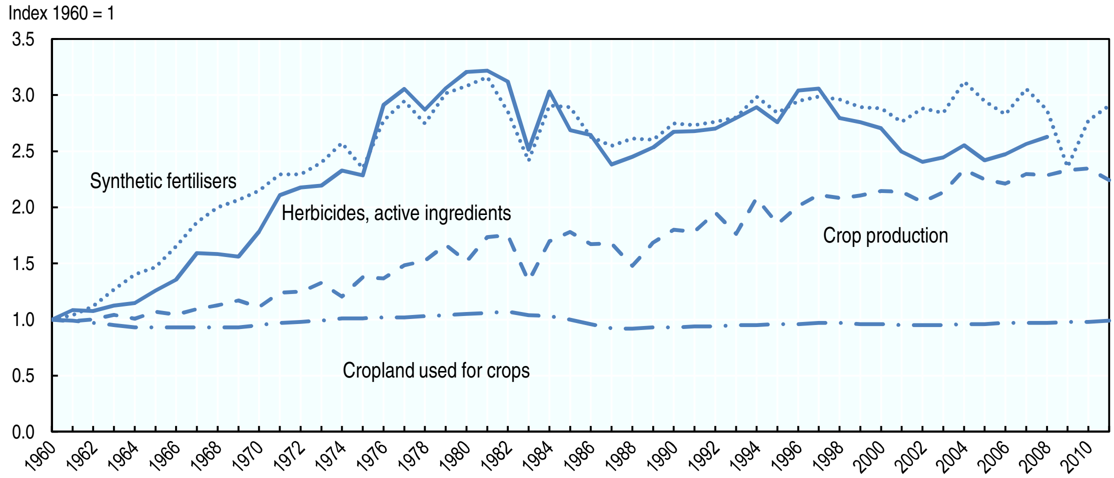
Total applications of synthetic fertilisers and chemical herbicides in US agriculture, when measured by the weight of active ingredients, increased by about 200% between 1960 and 1980 (Figure 2.17). Expanded use of those chemicals was associated with increased crop yields, and crop production grew by 50% between 1960 and 1980, even as the amount of cropland used for crops remained unchanged. However, total application of herbicides and synthetic fertilisers, as measured by pounds of active ingredients, shows no trend since 1980, although there have been substantial year-to-year fluctuations.

Figure 2.17. US crop land, crop production, and chemical use, 1960-2011



Source: USDA (2015h), National Agricultural Statistics Service, USDA (2015b), Economic Research Service. www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

StatLink http://dx.doi.org/10.1787/888933408241

Agricultural chemicals — primarily, synthetic fertilisers and pesticides — can boost productivity growth, by providing plant nutrients and limiting pest damage, but excessive applications can also generate externalities. Runoff of fertilisers and pesticides from fields can degrade drinking water quality in groundwater and rivers and streams, while volatilisation of chemicals can degrade air quality. Degraded air and water quality can harm human health, and can create further economic costs for other resource users.

The attributes of pesticides and synthetic fertilisers have changed, with some delivering greater effectiveness for lower volumes of active ingredients. The ERS productivity accounts adjust chemical inputs for changes in attributes; that series shows steady continuing growth in the effective pesticide input, amounting to 3.8% per year from 1980-2013. Almost all of that growth is due to changes in pesticide attributes, rather than growth in physical quantities applied.

Increased crop yields are often associated with improved take-up of agricultural nutrients, and reduced run-off and volatilisation of nutrients and pesticides. Research leading to improved crop yields, as well as research leading to more effective pesticides and synthetic fertilisers, or improved pest management practices, can also contribute to reducing the environmental pressures linked to the use of these inputs. Developments in biotechnology have contributed to those goals.

Biotechnology and input use

Biotechnology became important to US agricultural production when advances in molecular and cellular biology allowed scientists to introduce desirable traits from other species into crop plants (Phillips, 2013). The most commonly introduced genetically engineered (GE) traits augmented traditional strategies of pest management. They either allowed plants to produce their own insecticide, thus reducing yield losses to insects, or to tolerate herbicides, so that broad spectrum herbicides could be used to control weeds without harming crops.

There are several different insect resistant (IR) GE traits, aimed at different insects, as well as several herbicide tolerant (HT) traits for different herbicides. Other commercially available traits allow for virus resistance and drought tolerance. Seeds increasingly feature "stacked traits" — that is, multiple GE traits introduced into one seed.

GE HT and IR seeds were commercially introduced in 1996, and were planted on over 90% of US maize, cotton, and soybeans acres by 2015 (USDA/NASS, 2015). HT traits have been introduced for all three crops, and were used on 94% of soybean acres and 89% of maize and cotton acres in 2015; IR traits have not been introduced for soybeans, but were used on 84% of cotton acres and 81% of maize acres in 2015 (Figure 2.18). These three crops account for most acreage planted with GE seeds, but the seeds are also widely used in alfalfa, canola, papaya, and sugar beets.

Adoption of GE crops in the United States has been associated with substantial declines in insecticide use, and a substitution of the herbicide glyphosate for other herbicides (Fernandez-Cornejo et al., 2014). GE crops were developed to be tolerant of glyphosate, so it could be sprayed after plants emerged; it also displayed lower persistence in soils, superior performance in controlling a wide range of weeds, and declining retail prices after going off-patent. Glyphosate is thought to be less environmentally damaging than other herbicides (Phillips, 2013). Moreover, producers of HT crops are more likely to use conservation tillage techniques, which convey additional environmental and soil health benefits (Perry, Moschini, and Hennessy, 2016).

Farmers who adopt IR traits realise higher yields and increased net cash income. The effects of HT adoption on net cash income are ambiguous, but adopters realise reduced labour hours, which could then be reallocated to other farm, off-farm, or family activities (Fernandez-Cornejo et al., 2014; MacDonald, Korb, and Hoppe, 2013).

Intensive use has led to increased weed resistance to glyphosate, particularly in soybeans (Livingston et al., 2015). Glyphosate is far more effective than other herbicides in soybean production and by 2004 it accounted for over 80% of herbicide applications in soybeans (Figure 2.19). In contrast, glyphosate is only one of several herbicides used in maize production (Figure 2.20).

Resistance develops more rapidly where a single herbicide is used to control weeds, and where it is used over consecutive years. As glyphosate resistance spread widely in soybeans, farmers responded by increasing applications of glyphosate and other herbicides as well (Figure 2.19). In maize, where glyphosate resistance has spread more slowly, application rates of glyphosate and other herbicides continued to fall between 2008 and 2014 (Figure 2.20).

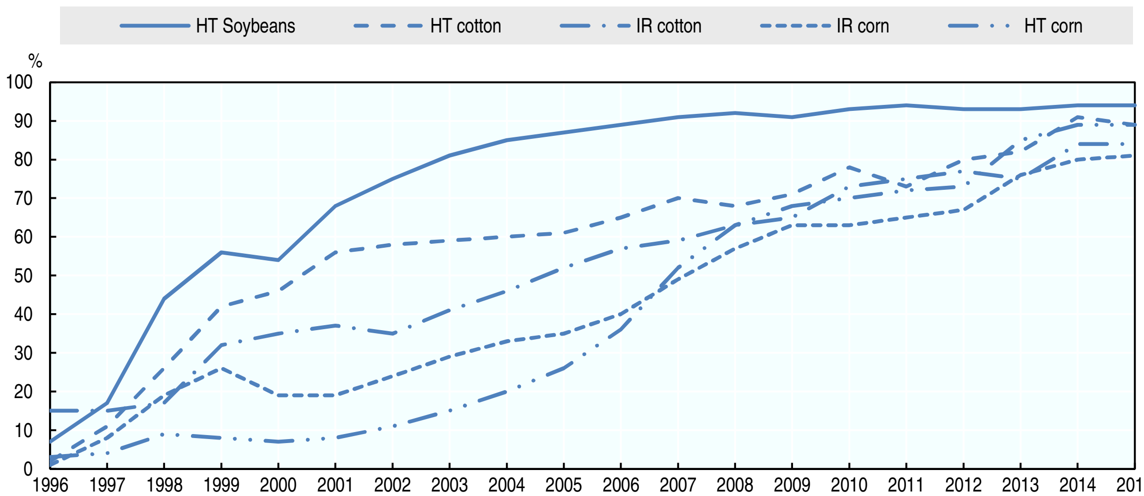
Active management of resistance, by varying the mode of action of herbicides, rotating crops and herbicides, and working jointly with neighbouring farms, yields positive net benefits for farmers at time horizons that exceed a year (Livingston et al., 2015).

GE crops have increased agricultural productivity by reducing the amount of labour required per unit of output (Fernandez-Cornejo et al., 2014). To the extent that GE crops require fewer field passes for spraying and tillage, they also reduce the amount of capital and energy required per unit of output. GE crops can also increase crop yields to the extent that they suppress pests that would not have suppressed by conventional means. Each of these impacts, as well as related reduction in environmental pressure, are attenuated as resistance develops among weeds or insects.

Diagnostic tools developed in association with genetic engineering have found application in conventional plant and livestock breeding. Tools such as marker-assisted selection allow for more rapid identification of desirable traits, and therefore speedier application of conventional breeding procedures.

Some ongoing research in agricultural biotech continues the focus on gene transfer. For example, some work aims to improve plant growth in grasses and field crops by increasing the efficiency of light capture during photosynthesis. The most successful approaches, not yet commercialised, involve introducing genes from photosynthetic bacteria into plants, without affecting the activity of other genes.

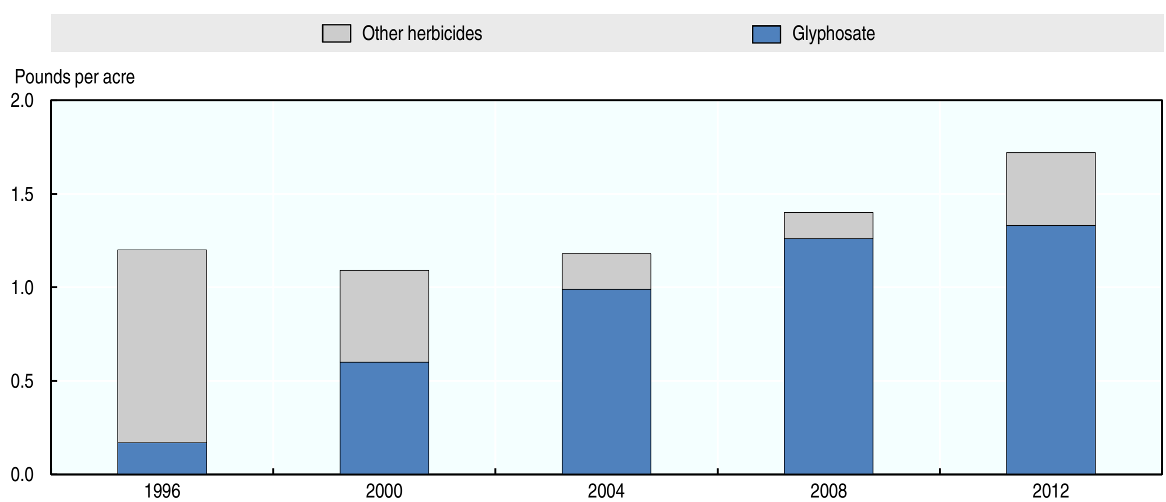
Figure 2.18. Adoption of genetically engineered seeds in the United States, 1996-2015



Source: 1996-99 are from Fernandez-Cornejo and McBride (2002), www.ers.usda.gov/publications/aer-agricultural-economic-report/aer810.aspx; 2000-2015 are from USDA (2015g), National Agricultural Statistics Service, Acreage Report http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1000.USDA).

StatLink http://dx.doi.org/10.1787/888933408255

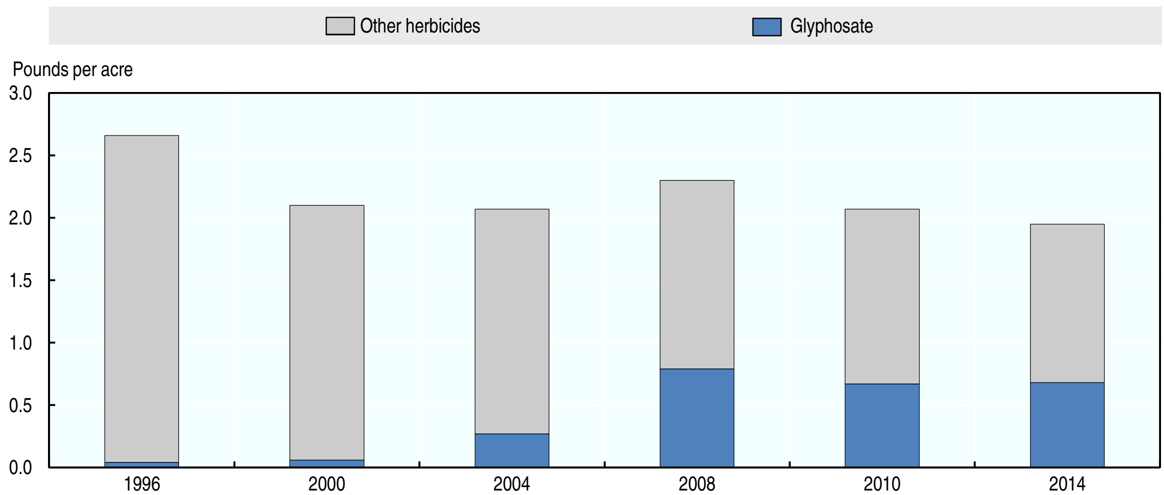
Figure 2.19. Herbicide application rates for soybeans, 1996-2012



Source: USDA (2015h), National Agricultural Statistics Service.
www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

StatLink http://dx.doi.org/10.1787/888933408265

Figure 2.20. Herbicide application rates for maize, 1996-2014



Source: USDA (2015h), National Agricultural Statistics Service. www.usda.gov/wps/portal/usda/usdahome?navid=DATA_STATISTICS.

StatLink http://dx.doi.org/10.1787/888933408271

More recent developments in biotechnology are focusing on gene editing — the ability to cut and alter the DNA of a species at almost any genomic site (Mayaguez, 2016). Gene editing techniques forego the introduction of genes from one species into another, thus avoiding one of the major objections to prior GE products. Related techniques allow scientists to make precise mutations, to disable genes by snipping them out of DNA sequences, or to enhance or suppress gene expression. In labs and field experiments, the technologies have been used to edit crop strains for drought resistance and herbicide tolerance; to extend the growth phase of plants by reducing seed dormancy or by preventing or delaying flowering; to create virus resistance in certain swine varieties; and to alter musculature in cattle. These developments will create new types of biotechnology products, but may also create new types of market, environmental and safety risks, and may require adjustments in biotechnology regulatory processes.

Sustainability performance

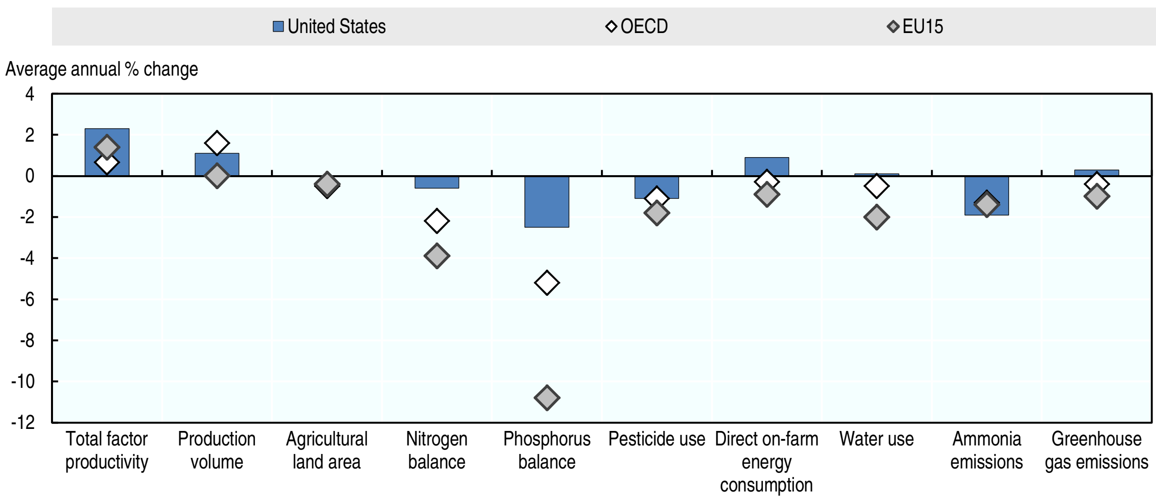
Overall sustainability performance

Agricultural production, depending on how it is performed, can degrade or conserve soil, water, and air resources. Sustainability outcomes can arise as the result of the intended or unintended consequences of innovations, policies, or production decisions. Measures of US sustainability performance show improvements, which can be traced to important policy initiatives.

Most environmental pressures from agriculture trended downward in the United States during the last decade including: nitrogen and phosphorus surplus per hectare of agricultural land, pesticide use, and ammonia emissions from agriculture (Figure 2.21). Other indicators are relatively stable in time, such as water abstraction, greenhouse gas emissions, and direct on-farm energy consumption (slightly increasing). These improvements follow those observed in the OECD and EU15 areas, although of a lower magnitude –partly due to the fact that initial levels of environmental pressures were lower in the United States for some indicators (e.g. nutrient surplus).

Decreases in environmental pressures have been accompanied by a significant increase of agricultural production, essentially arising from growth in total factor productivity. As explained above, such productivity gains allowed farmers to produce more with less land and inputs (fertilisers, chemicals and water), leading to environmental decoupling of agricultural production nationwide.

Figure 2.21. Development of environmental indicators for agriculture, United States, OECD and European Union, 1998-2000 to 2008-10



Recent data show a significant increase in pesticide use since between 2008 and 2013, mainly due to increasing herbicide sales.

Source: OECD (2013), OECD Compendium of Agri-environmental Indicators, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264181151-en.; USDA (2015e), Economic Research Service, International Agricultural Productivity Database. www.ers.usda.gov/data-products/international-agricultural-productivity.aspx.

StatLink http://dx.doi.org/10.1787/888933408289

This reduction of environmental pressures from agriculture has resulted in improvement or maintenance of the state of the environment in many places. For example, pesticide concentration in groundwater has been relatively stable or decreasing over the last two decades; at worst slightly increasing in some cases (Toccalino et al., 2014). Although pesticides are frequently detected in samples (53%), the proportion of samples with pesticide concentrations posing a problem for human health has been estimated at 1.8% per year by (Toccalino et al., 2014).

Despite this general improvement, there still exist areas with significant environmental problems linked to agriculture, such as: water shortages in California due to a series of serious drought events in recent years; hypoxic zones in the Gulf of Mexico due to excessive nutrient pollution of the Mississippi River (mainly from agricultural sources); local pollution of microbial pathogens and pharmaceuticals in areas with concentrated animal feeding operations (CAFOs); or excessive soil erosion in some geographical areas. More generally, agriculture remains a primary threat to habitats and associated biodiversity in the United States. Recent trends in herbicide sales indicate that pesticide use is significantly trending upward since the late 2000s. The higher total pesticide use in the last decade is in response to declining effectiveness of some herbicides and expanded maize and soybean acreage.

Land conservation

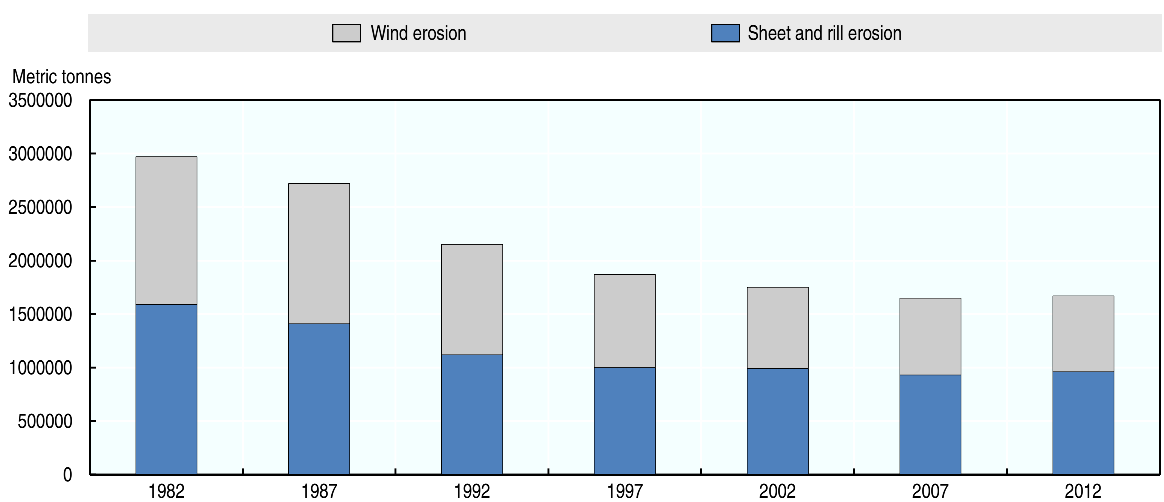
In 2012, just over 913 million acres (369 million ha) were used for agricultural production, excluding federal land leased for grazing, which is not separately identified (Figure 2.2). More than half of agricultural land is in grazing use as rangeland and pasture, with the rest in cropland and conserving uses –primarily land in the Conservation Reserve Program (CRP). Between 1982 and 2012, the total area of land used for agriculture declined by 58 million acres or roughly 6%. While some of the land leaving agriculture shifted to forest uses, most went to metropolitan development.

In recent years, a significant share of environmentally sensitive agricultural land has been withdrawn from production and placed in the CRP. Most CRP land is cropland that producers and landowners have agreed to place in conserving use (usually grass or trees) for 10 years or more. In exchange, producers receive cost-sharing for establishment of cover and annual payments that are roughly equal to the income forgone. At the programme's peak in 2007, 36 million acres (14.5 million ha; 9% of cropland) was enrolled, compared to 24 million acres at the end of 2015. After 2007, high prices for crop commodities drew more acreage into crop production, with much of that coming from the CRP.

CRP average per-acre rental rates were increased by 16% over 2007-13, but this was substantially less than the 74% increase in average cropland rental rates over the same period; without programme adjustment, rising commodity prices are likely to draw land out of CRP (Hellerstein and Malcolm, 2011). Since 2007, CRP has also focused spending on high-priority practices like riparian buffers, field-edge filter strips, and wetland restoration, as well as State-Federal Partnerships through the Conservation Reserve Enhancement Program. These types of enrolments are thought to provide higher levels of environmental benefits per acre than the whole-farm or whole-field enrolments that still account for 75% of CRP area. Thus, declines in CRP enrolled area reflect both market forces and policy choices (Claassen, 2014).

Soil erosion on US cropland declined substantially between 1982 and 2012 (Figure 2.22). In 1982, total soil erosion on cropland was estimated at 2.69 billion metric tonnes) per year. By 2012, total cropland erosion had dropped to 1.51 billion metric tonnes per year, a 43% decline. Most of the reduction in cropland erosion occurred by 1997, when erosion was reduced to 1.70 billion metric tonnes per year. Large reductions in both rainfall (sheet and rill) and wind erosions were recorded. Contributing to the decline in soil erosion was the placement of sensitive cropland in the CRP and the adoption of soil and crop management technologies like conservation tillage.

Figure 2.22. Soil erosion on cropland, 1982-2012



Source: USDA (2015j), Natural Resource Conservation Service, Natural Resources Inventory. www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/.

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Nutrient use efficiency

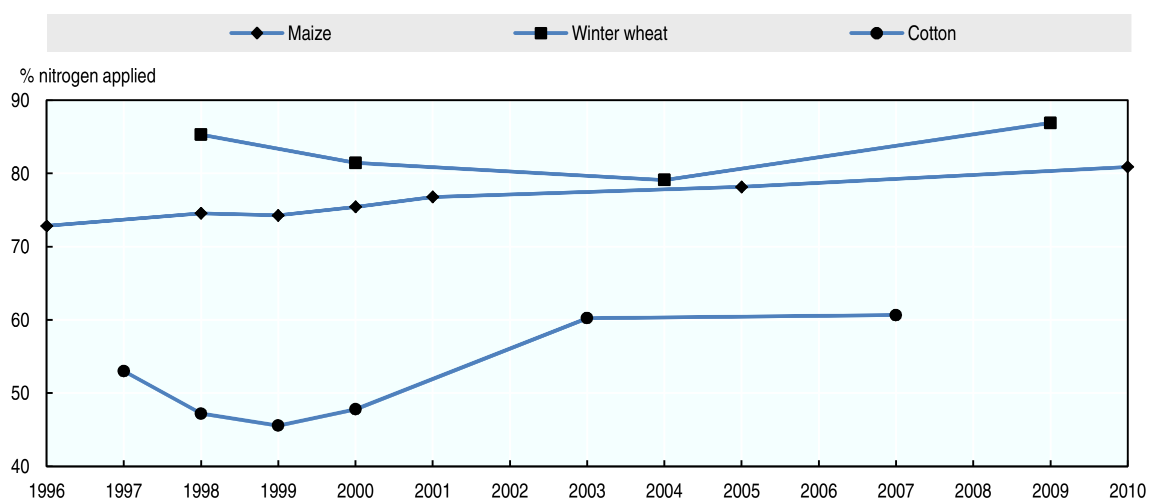
A large majority of major crops grown on US farms receive some type of fertiliser or manure. Commercial nitrogen, for example, was applied to 96% of maize in 2010, 83% of winter wheat in 2009, and 92% of cotton in 2007 (USDA-ERS). Manure was applied to 15% of maize in 2010, 2.4% of wheat in 2009, and 3.2% of cotton in 2007. Some portion of applied nutrient, which is not used by the crop, can be lost to the environment through runoff, leaching, or volatilisation.

The nutrient recovery rate is the ratio of the amount of nutrient in the harvested crop to the amount of nutrient applied. Partial recovery occurs when the amount applied exceeds the amount removed. For maize, nitrogen recovery efficiency increased from 73% in 1987 to 81% 2010, while phosphate recovery hovered near 100% (Figures 2.23 and 2.24). For soybeans, phosphate recovery is above 100%, suggesting that phosphates are actually mined from the soil.

US cropland area where excess nutrients are applied is declining. For maize, the share of planted acres with excess nitrogen applied (above 25% of the crop's needs) declined from 59% in 1996 to 47% in 2010, while the share of acres with excess phosphate declined from 43% in 1996 to 31% in 2010 (Figures 2.25 and 2.26). Other crops also exhibit either declining or unchanged shares of planted acres with excess use of nitrogen or phosphate.

Nutrient use efficiency has been increased largely through higher yields and improved nutrient management practices. Higher yields result in more nutrients being removed from the soil, thus reducing nutrient losses. Yields (and efficiency) have benefited from increased crop rotation (maize planted after soybeans), soil testing for nitrogen, use of GE seeds to reduce pest damage, increase in seeding rate, and adoption of precision technology (such as yield monitors and soil map).

Figure 2.23. Crop nitrogen recovery rates, 1996-2010



Source: ERS calculation from USDA (2015a) *Agricultural Resource Management Survey* (ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

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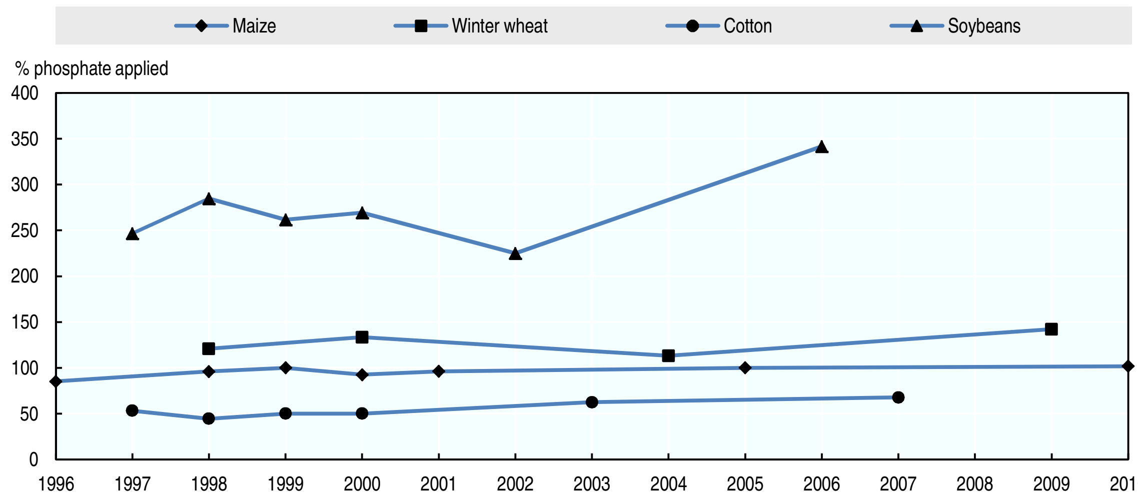
Figure 2.24 Crop phosphorous recovery rates, 1996-2010



Source: ERS calculation from USDA (2015a), *Agricultural Resource Management Survey* (ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

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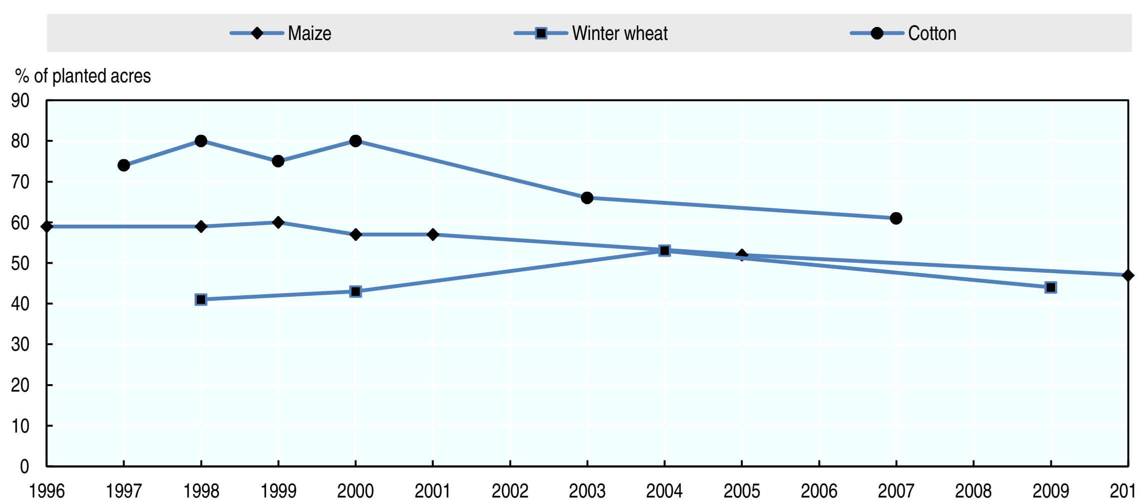
Figure 2.25. Planted areas receiving excess nitrogen, 1996-2010

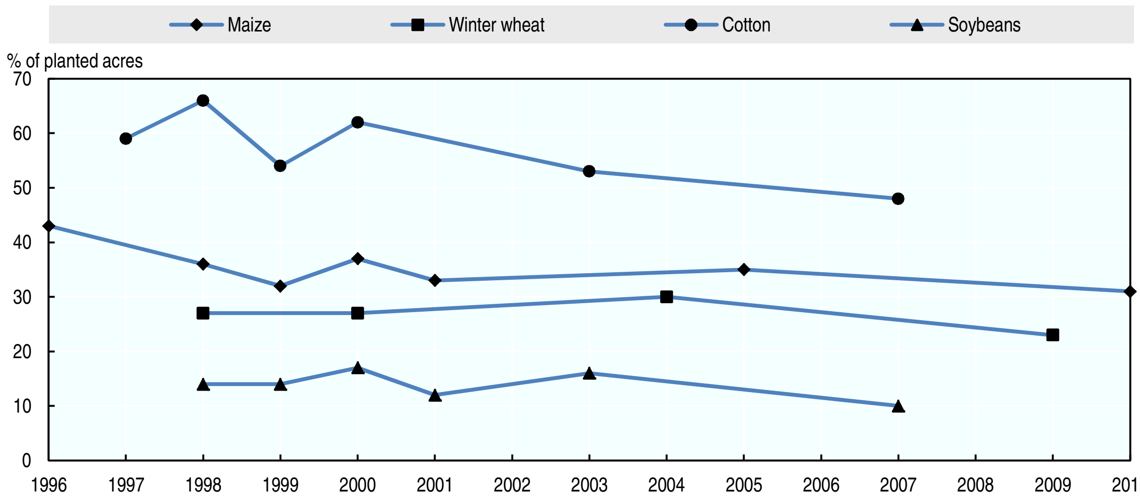


Nutrients application that exceeds crop need by 25% are considered excess.

Source: ERS calculation from USDA (2015a), *Agricultural Resource Management Survey* (ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/888933408326

Figure 2.26. Planted areas receiving excess phosphorous, 1996-2010



Nutrients application that exceeds crop need by 25% are considered excess.

Source: ERS calculation from USDA (2015a), *Agricultural Resource Management Survey*(ARMS), Phase II. www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/888933408338

Research suggests, however, that additional improvement in nutrient use efficiency could be obtained by increasing adoption of nutrient management best management practices (BMPs). Wade et al. (2015) show that only 24% of cotton acres and 6% of maize acres combined four nutrient management practices for nitrogen: 1) no application in the fall, 2) some application after planting, 3) application at rates below a nutrient management "benchmark" rate, and 4) fertilisers incorporated or injected below the soil surface. Nonetheless, many farmers now use one or more nutrient BMPs, contributing to the overall increase in nutrient use efficiency.

Production has concentrated into larger farms and fewer locations, which in some places led to stocks of manure nutrients that exceeded local crop needs. Consolidation in US livestock production has had complex effects on nutrient use and disposal: concentration can increase local pollution; but at the same time this can be partially offset by higher feed efficiency on larger farms. Improvements in feed conversion reduce the amount of manure created and the amount of feed required for any given volume of meat production. For example, ERS analyses indicate that feed conversion in pig finishing operations fell from 3.83 pounds of feed per pound of weight gain in 1992 to 2.07 by 2009 (McBride and Key, 2013). Feed conversion improvements have also occurred, more slowly, for broilers: from 2.08 pounds in 1980 to 1.74 in 2011, for the same 4 pound size of bird (MacDonald, 2014).

However, concentration has led to several major events associated with failures of manure storage structures, and to concerns with excessive applications of manure, resulting in expanded regulation as well as litigation. For example, a pig waste lagoon in North Carolina overflowed in 1995, dumping over 20 million gallons of pig waste in the New River, and a hurricane in 1999 led to further flooding of North Carolina pig waste lagoons and contaminated water supplies. The state, the second largest pig producer, imposed moratoriums on pig farm construction in 1995 and on farms with lagoons in 1999. Elsewhere, the attorney general of the state of Oklahoma initiated a lawsuit against 14 poultry companies in the adjoining (and upstream) state of Arkansas, concerning run-off of phosphorus from poultry litter into the Illinois River watershed. In Texas, the City of Waco initiated a lawsuit against 14 large dairy farms near the city, concerning the effects of dairy manure on phosphorus levels in the North Bosque River and Lake Waco, the source of the city's drinking water. The suit was settled with an agreement on waste management practices between the farms and the city.

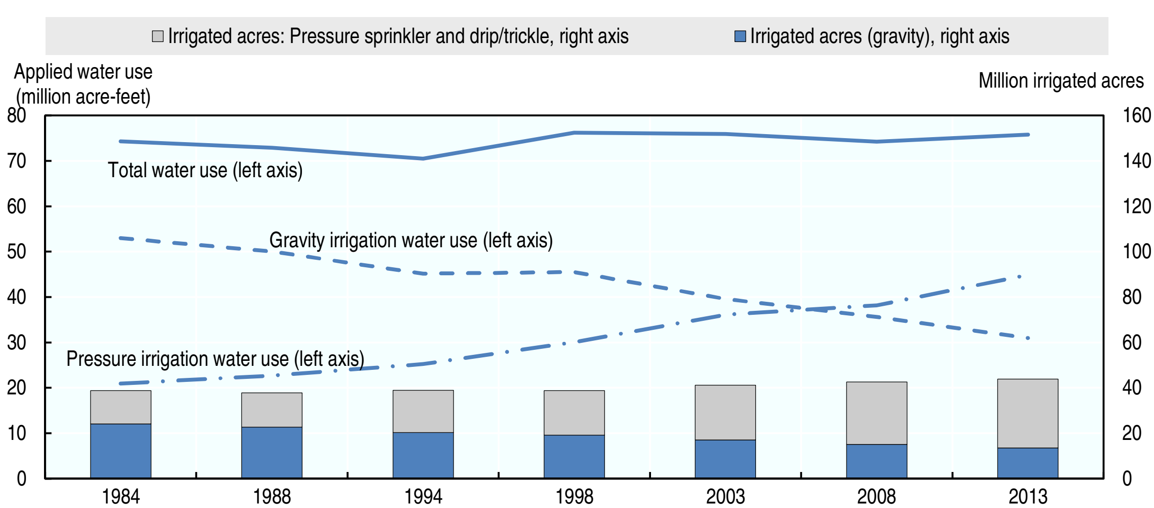
Agricultural water use

Roughly 56 million acres (22.7 million ha) — or 7.6% of all US cropland and pastureland — were irrigated in 2012. Nearly three-quarters of irrigated acres are in the 17 western-most contiguous States (Western States). USDA's Farm and Ranch Irrigation Survey (FRIS) reports that in 2013, farmers and ranchers applied 91.2 million acre-feet of water (an acre-foot of water is equivalent to 325 851 gallons, or 1 233 cubic metres). The US Geological Survey (USGS) estimates that irrigated agriculture accounted for 38% of the Nation's freshwater withdrawals from sources like rivers, lakes or aquifers in 2010. Some water withdrawals are eventually returned to sources. Agriculture accounts for approximately 80 to 90% of consumptive water use in the United States. Water that is consumed — e.g. for crop growth and transpiration in agriculture — is not returned to the source.

In recent decades, on-farm irrigation efficiency — the share of applied water that is beneficially used by the crop — has increased (Figure 2.27). In 1984, gravity systems — where roughly 54% more water per acre is applied compared with pressurised systems, on average — accounted for more than 70% of all water applied for crop agriculture in the 17 Western States. By 2013, gravity systems applied less than half of all irrigation water, while water used with pressure systems accounted for 59% of water applied.

Irrigation is widely viewed as an important adaptation to shifting production conditions under climate change. However, Marshall et al. (2015) project that irrigated field crop acreage in the United States will decline over 2020 to 2080 due to competition over water supplies, which are anticipated to decline in certain areas. Before mid-century, the decline in irrigated acreage is largely driven by regional constraints on surface-water availability for irrigation. Beyond mid-century, the decline reflects a combination of increasing surface-water shortages and declining relative profitability of irrigated production. Crop production is expected to shift toward rain-fed growing conditions. There are water stress hotspots in some regions, which could be exacerbated by climate change.

Figure 2.27. Irrigated acres and water use, 1984-2013



Source: USDA (2014), *Economic Research Service Farm and Ranch Irrigation Survey* (FRIS) data. www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background.aspx.

StatLink http://dx.doi.org/10.1787/888933408348

Climate change mitigation and adaptation

Climate change is expected to result in higher and more variable average temperatures during growing seasons, to alter the seasonality of rainfall, and to increase the incidence of extreme weather events and pest and disease pressures. These developments could have significant effects on crop yields and prices (Malcolm et al., 2012; Schlenker and Roberts, 2009).

Nationwide, the impact of climate change on income from the crop sector is uncertain: it could be negative, with aggregate losses of up to USD 1.5 billion; or positive, with gains of up to USD 3.6 billion. Much of this uncertainty is related to the difficulty in estimating hydrological impacts of climate change, particularly at local level (Malcolm et al., 2012).

The impacts of climate change on yields and incomes of American agriculture are likely to vary widely between regions. It is estimated that the southern regions will suffer more significant yield reductions. Malcolm et al. (2012) estimate current losses related to climate change in the Corn Belt crops sector between USD 1.1 and 4.1 billion. This is in addition to losses related to plant disease estimated between USD 400 and 600 million (Malcolm et al., 2012).

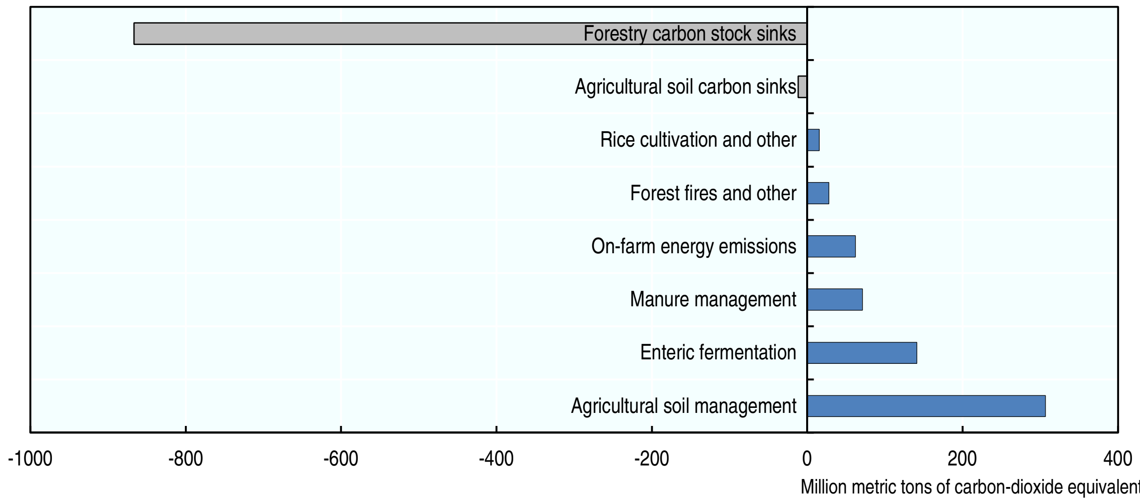
Other studies show more concerning climate change impacts on agriculture (OECD, 2014; Schlenker and Roberts, 2009). In that regard, the assumptions made about the possibilities of adaptation by farmers (rotation changes, inputs, production relocations) are crucial to estimate the net impact — that is to say, after adaptation of climate change on agriculture. These options depend on institutional, economic and social conditions, in addition to natural conditions (soil, climate). A recent study tends to show that flexibility needed for adaptation may be relatively satisfactory in the crop sector, but less in the livestock sector (Yang and Shumway, 2015).

The adaptation response to climate change — changes in crop acreage and input use —is likely to increase environmental pressures from agriculture in certain regions. For example, Malcolm et al. (2012) estimate that cropland area could increase by up to 1% and nitrogen fertiliser losses by up to 5% due to adaptation responses. This may increase pollution problems in some areas, and suggests that policy responses to pollution problems may need to take account of negative, unintended effects of adaptation responses.

In terms of Greenhouse Gas (GHG) emission, agriculture is an emissions intensive sector. The agriculture and forestry sectors together accounted for 10.4% of US greenhouse gas emissions in 2012, while accounting for less than 1% of GDP. Crop and pasture soil management are the activities that generate the most emissions, due largely to the use of nitrogen-based fertilisers and other nutrients (Figure 2.28). The next largest sources are enteric fermentation (digestion in ruminant livestock) and manure management. Agriculture and forestry are unique in providing opportunities for withdrawing carbon from the atmosphere through biological sequestration in soil and biomass carbon sinks.

Land-based activities with the highest potential for sequestering carbon are conversion of cropland and pasture land to forest uses (afforestation), and management of forest land. In addition, changes in agricultural practices and land uses can reduce GHG emissions. For land remaining in crop and pasture uses, activities with the highest potential include improved grazing management on rangeland and pasture, retirement of cropland (through the CRP, for example), adoption of no till on cropland, and land use change from cropland to less intensive farmland uses. Improved fertiliser management (e.g. reducing application rates and using slow-release fertiliser or nitrification inhibitors) can reduce GHG emissions from soils. Changes in livestock management that focus on the reduction of methane emissions and the capture of biogas (e.g. improved diet and installation of anaerobic digesters) also offer mitigation potential; however, some manure management approaches (such as handling manure in solid form, via composting) could increase GHG emissions.

Figure 2.28 Agriculture and forestry greenhouse gas emissions and sequestration, 2012



Negative values indicate carbon sequestration. Forestry sink includes afforestation and forest management.

Source: ERS calculation using US Environmental Protection Agency (2015), *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2012*. www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

StatLink http://dx.doi.org/10.1787/888933408352

Summary

- The United States has a large competitive agricultural sector, which accounts for a small share of GDP and employment. With abundant land and water resources, and diverse climatic conditions, it produces a wide range of commodities, split evenly between crop and livestock products. The country is a net exporter of agri-food products, which account for a significant share of total exports.

- Changes in food consumption include an increased preference for poultry over red meats, for fresh fruit over processed fruit; more processed potatoes; and more fresh green vegetables. There is also an increase in food consumption away from home, and food purchased outside supermarkets. There is widespread and growing interest in food with specific product attributes, such as distinct varieties of fruits, meat from specific pork breeds, or coffee from specific locations, as well as organic products.

- These developments have led to several important changes in agricultural production and food processing and distribution, as well as the composition of US agri-food exports. For example, the share of fruits and vegetables, in particular nuts, in production and exports has increased. Higher exports of animal products also respond to global growth in demand for those products from a wealthier population.

- There is also growing interest among US food consumers and retailers in how farm products are produced, and not just in the sensory attributes of the products themselves. Organic agriculture for example is growing rapidly, as well as direct sales at farmers' markets. These shifts create a growing demand for public and private certification services.

- Agricultural production has consolidated into larger farms. Consolidation has occurred in all commodity sectors and regions, but even so family farms still dominate the sector. Moreover, a high diversity of farm operations remains, in terms of farm size and activities. Developments in both farm size and off-farm activities by farm household operators have been permitted by the adoption of labour-saving technologies.

- Farm income can vary sharply from one year to the other, although agricultural policies contribute to reducing the variability of farm receipts. In addition, farm income is only part of total farm household income, which on average grew more rapidly than those in the overall economy. The average for the US operators of commercial farms now earn household incomes that are in line with owners of other small-to-midsize businesses in the US economy, which is an important factor in attracting talented people to the industry, and in retaining them. High farm incomes are associated with increased in farm equipment purchases, and thus contribute to the diffusion of innovation.

- Most processors, retailers, and input providers are large corporations. There is little vertical integration between agriculture and other parts of the food system, but farms are often tightly linked with other firms in the food system through various types of contractual relationships. For example, US farmers use contracts and leases for many inputs; and large retailers set procurement standards. Food processing industry concentration has increased over time, raising issues regarding concentration in some sectors. Farmer-owned cooperatives play a major role in the marketing of farm commodities and the purchase of farm inputs. Some have grown quite large and have diversified services.

- US agriculture achieves high levels of productivity and productivity growth. Agricultural productivity has grown steadily since at least the 1940s. The country has been able to increase total agricultural output by 169% between 1948 and 2013, while reducing the amount of land and labour devoted to agriculture. That growth has come largely through the application of a series of innovations in crop and livestock breeding, nutrient use and pest management, farm practices, and farm equipment and structures, most of them developed from public investments in scientific research. Productivity growth is linked to adoption of new technology, including genetically engineered (GE) seeds, and practices, as well as changes in the composition of inputs. Moreover, geographical shift in production to take opportunity of better conditions contributed to increased yields.

- Productivity growth rates in agriculture are high when compared to the rest of the US economy, and just offset slow productivity growth and added services in the rest of the food system to keep food prices rising at the same pace as consumer prices. Productivity growth in agriculture constrains food prices, but that effect is modest because farm commodities account for a small share of retail food costs. A major effect of agricultural productivity growth has been to free resources — of labour, land, and capital that would have been needed to produce food — for use elsewhere in the economy.

- High productivity performance in the 2000s has been achieved with an overall reduction in environmental pressures from agriculture, as illustrated by trends in agri-environmental indicators. This has resulted in improvement or maintenance of the state of the environment in many places. Despite this general improvement, there are still areas with significant environmental problems linked to agriculture, such as water shortages and excessive nutrient pollution at regional or local levels; pesticide sales are significantly trending upward since 2008; and agriculture remains a major threat for ecosystems in several regions.

- Climate change is likely to have deep implications for agricultural production and incomes in the coming decades, especially in some regions that combine higher sensitivity and exposure to climate changes, and fewer opportunities to adapt. Aggregate impacts of climate change may be limited, but regional impacts much more significant. Indirect effects through pests and diseases remain largely unknown. Finally, adaptation responses could also have negative impacts on the environment through changes in crop acreages; increases in input use.

- Changes in demand at global and US levels provide opportunities for US agri-food products, but the rise in concerns about the way food is produce imposes new constraints. Climate- and resource-related constraints create new challenges in meeting those demands, while maintaining past high productivity performance and improving sustainability. Enormous opportunities arise from new science but they will materialise only if stakeholders and society accept those innovations.

Note

1. See Huffman and Evenson (1993, 2006), Alston et al. (2010, 2011), Wang et al. (2012), and Jin and Huffman (2016) for evidence on the long-term link between public investment in agricultural R&D and TFP growth in US agriculture. Table 7.5 provides estimates of the internal rate of return to public investments in agricultural research from various studies.

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Chapter 3

ECONOMIC STABILITY AND TRUST IN INSTITUTIONS IN THE UNITED STATES

This chapter outlines the importance of economic stability and public institutions in fostering public and private investment. It provides an overview of the performance of the overall economy, outlines macroeconomic developments and challenges, explains the federal-state-local governance system, and presents an evaluation of public institutions.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Macroeconomic policy environment

At the broadest level, stable and sound macroeconomic policies, leading to high growth and low and stable inflation rates, play an important role in setting a favourable environment for investment in farms or agri-food firms seeking to introduce new products, to adopt new production methods, or to undertake organisational changes that can lead to higher productivity growth and more sustainable use of natural resources. Assessment of the country's overall growth and growth potential in the short- to medium-term has implications for sector specific prospects as well. In some circumstances, macroeconomic policies and their impacts can contribute to implicit and perhaps unintended biases for or against the food and agriculture system.

The United States is a large economy with well-established institutions to manage economic policies. Monetary policy is carried out by an independent central bank, the Federal Reserve (the Fed), through a policy-making body called the Federal Open Market Committee (FOMC). The Fed's monetary policy directives are carried out primarily by the Federal Reserve Bank of New York, one of 12 regional Federal Reserve Banks, and the deep US financial markets allow for the use of a wide range of tools. Fiscal policy is carried out jointly by Congress and the President, with analytic and data support from the President's Council of Economic Advisors, the Department of the Treasury, and the Congressional Budget Office. Some fiscal policy actions — increases in expenditures or reductions in taxes — occur automatically through the design of existing statutes, without explicit immediate actions taken by policymakers (these are called automatic stabilisers). Other fiscal policy initiatives require explicit actions by policymakers.

The US economy was hard hit by the recession and financial crisis of 2007-09 (Figure 3.1). House prices, which had risen to unprecedented levels over the previous decade while accompanied by a residential construction boom and a proliferation of complex mortgage-related financial assets, started to fall in early 2007. The fall in house prices, and the associated declines in household wealth and the value of mortgage backed and related assets, led to a slowdown in consumer spending, increases in mortgage defaults and home foreclosures, reduced credit availability, and significant strains on financial institutions (Council of Economic Advisors, 2010).

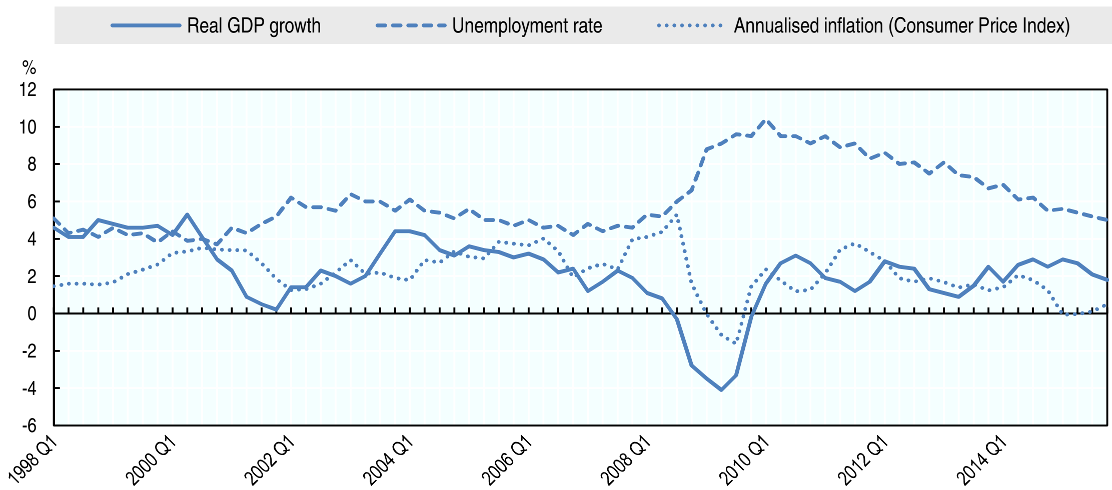
In the fall of 2008, the financial crisis intensified with the collapse of the investment bank Lehman Brothers and the near collapse of American International Group, a major insurer. Parts of the financial system froze, and seemingly safe asset classes became subject to "bank runs" as asset holders raced to dispose of them. Credit became considerably tighter, the stock market declined, and unemployment rose sharply as business activity slowed.

Real growth in Gross Domestic Product (GDP), which had begun to slow in late 2006, turned negative in 2008. Real GDP then contracted rapidly — at a 3-4% annual rate — through the first half of 2009. The civilian unemployment rate, which was at 4.2% in the 2nd quarter of 2006, reached 10.4% in the first quarter of 2010. This was the deepest recession since the Great Depression of the 1930s.

Recovery from the recession occurred slowly, like other recoveries after major financial crises (Reinhart and Rogoff, 2009). The financial crisis created sharp reductions in household wealth, which led households to reduce consumption expenditures as they sought to rebuild wealth stocks. Real GDP grew at an average annual rate of 1.9% between first quarter of 2010 and the first quarter of 2014.

Seven years after the crisis, the US economy has recovered, but growth has been moderate at 2.4% of GDP per year in 2014 and 2015, and is expected to remain around 2% in 2016 and 2017 (OECD, 2016). Macroeconomic imbalances and fiscal sustainability have been largely restored, as explained below, although general government net debt accounted for close to 88% of GDP by 2013 and is expected to reach 90% in 2016.[1]

Figure 3.1. US GDP growth, unemployment and inflation, 1998-2015



Data are quarterly averages; real GDP growth and inflation are reported as annualised percentage changes, compared to four quarters earlier.

Source: St Louis Federal Reserve Bank (2015), Federal Reserve Economic Data (FRED). https://research.stlouisfed.org/fred2/.

StatLink http://dx.doi.org/10.1787/888933408365

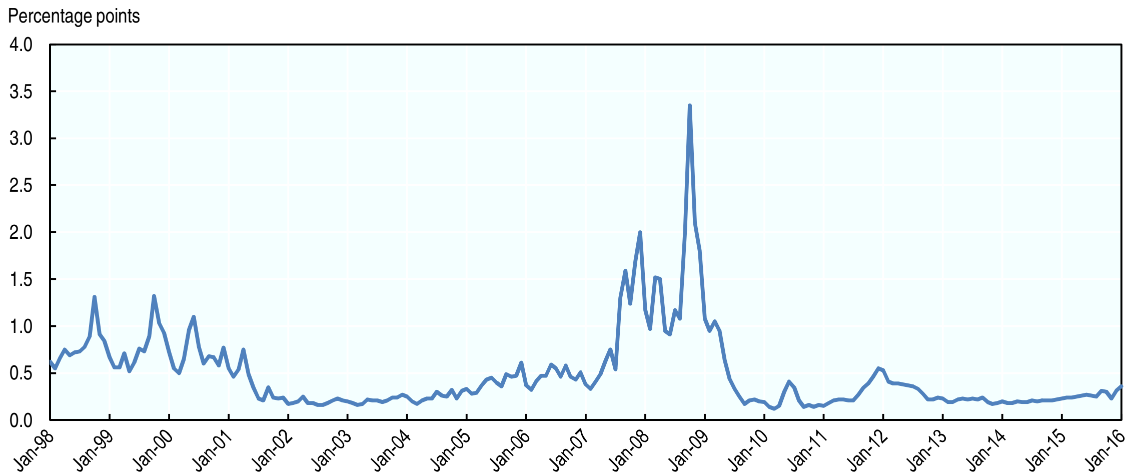
During the recovery, the unemployment rate continued to fall gradually to 4.9% in January 2016, and is expected to remain at 5% in 2016 and decrease to 4.7% in 2017 according to OECD projections. Private job growth, driving unemployment down to its structural level, has been a major element of the recovery from the crisis (OECD, 2016).

The crisis presented enormous challenges for central banks, as financial institutions strove to buy the safest financial assets and dispose of riskier assets, while also reducing lending for many business activities. As financial institutions sought the safest securities, prices for those securities were driven up, reducing their effective interest yields; as institutions tried to sell assets perceived to be riskier, those asset prices fell and their interest yields rose. Short and long-term credit for many activities dried up in the fall of 2008, leading to the spectre of a depression.

One measure of perceived credit risks is the TED spread, the difference in annualised interest rates between three-month US Treasury bills (viewed as the safest of assets), and interest rates that banks charge one another for overnight loans. The spread falls in a range of 0.1 to 0.3 percentage points in normal periods, reflecting the slightly higher risk associated with overnight loans among banks. However, the spread ranged from 1.0-2.0 percentage points in 2007-08 during a period of heightened credit risks, before rising to 3.35 percentage points in October 2008, as the crisis peaked and market participants surged into treasuries in a flight to safety (Figure 3.2).

Global trade, which is financed by institutions throughout the financial sector, fell sharply during the crisis (Figure 3.3). Merchandise trade is quite sensitive to changes in income, and declines in GDP would therefore have led to disproportionate declines in import demand, but trade financing also became difficult to access during the crisis. After growing by 24% between the beginning of 2005 and the end of 2007, global trade volumes stopped growing in 2008, and then plunged by 16% in the last quarter of 2009 alone. The global volume of merchandise trade did not return to its 2007 volume until the second half of 2010, and has grown slowly since.

Figure 3.2. The TED spread, monthly averages, 1998-2015

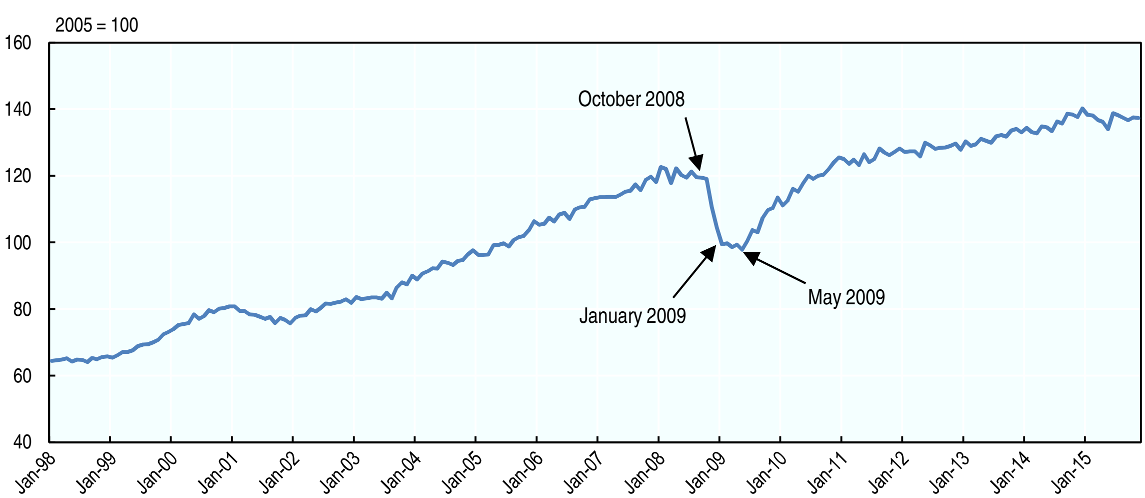


The TED Spread is the difference between interest rates charged on interbank overnight loans and 3-month US Treasury bills. It is a measure of credit risk in the US economy.

Source: St Louis Federal Reserve Bank (2015), Federal Reserve Economic Data (FRED). https://research.stlouisfed.org/fred2/.

StatLink http://dx.doi.org/10.1787/888933408373

Figure 3.3. World trade during the financial crisis, 1998-2015



Source: CPB (Netherlands Bureau for Economic Policy Analysis) (2016), *World Trade Monitor*. Seasonally adjusted merchandise trade. www.cpb.nl/en/world-trade-monitor.

StatLink http://dx.doi.org/10.1787/888933408382

As implied by the figures on global merchandise trade, the financial crisis and recession were global economic phenomena. At the trough, global industrial production fell by 14% from its previous peak. The initial declines in production and trade mirrored those of the Great Depression of the 1930s (Eichengreen and O'Rourke, 2012).

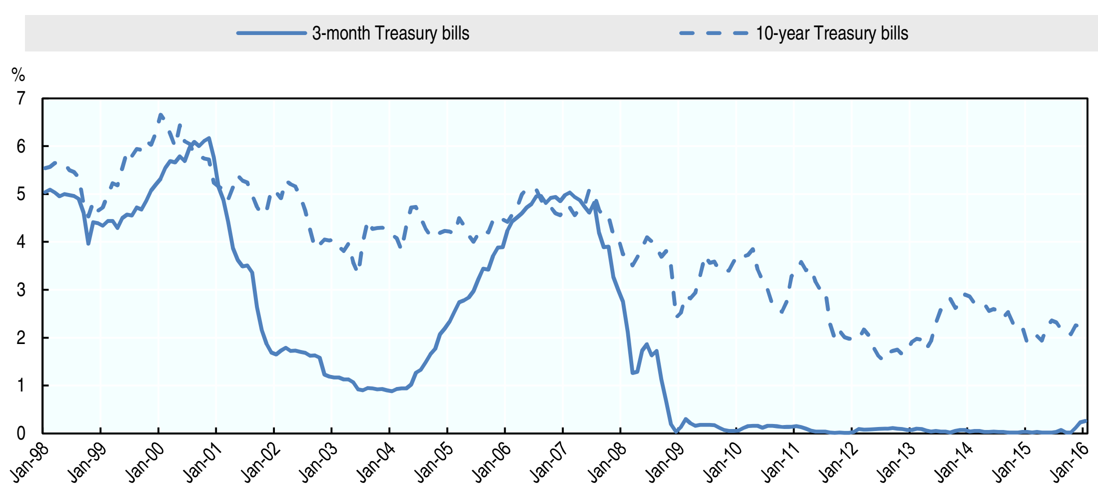
The Federal Reserve (Fed) and other central banks took extraordinary steps to resolve the global crisis by extending credit to, and purchasing financial assets from, bank and non-bank financial institutions. The impact of their actions on perceived risks in the financial system can be observed through the decline in the TED Spread, to 1% through the first quarter of 2009 and to 0.2% by the summer of that year.

The Fed also acted through traditional and non-traditional monetary policy channels to reduce interest rates (Figure 3.4). Rates on 3-month Treasury bills fell from 4.7% in August 2007 to 1.7% a year later as the Fed expanded short-term credit; they then fell to 0.19% by November 2008, and remained below 0.20% until December 2015.

In addition, the Fed took steps to reduce long-term interest rates through purchases of long-term securities in programs known as quantitative easing. Rates on 10-year Treasury bonds fell from 4-5% before the financial crisis, and remained near historic lows, at an average of 1.78% in February of 2016. However, low long-term rates likely also reflect slow global growth and large volumes of global savings.

Aggressive central bank actions have not led to increased inflation. In the United States, annual inflation as measured by the Consumer Price Index (CPI) ranged between 2 and 4% between 2000 and 2007 (Figure 3.1). It surged briefly to 5.3% in the 3rd quarter of 2008 as food and fuel prices rose, but inflation then fell off in the financial crisis and recession, and the CPI actually fell during the 2nd and 3rd quarters of 2009. CPI inflation has remained below 2% since the 1st quarter of 2012, in spite of falling unemployment and growing real GDP. It was even close to zero in 2016, but is projected to increase in 2016 and 2017 (OECD, 2016).

Figure 3.4. US interest rates, 1998-2015

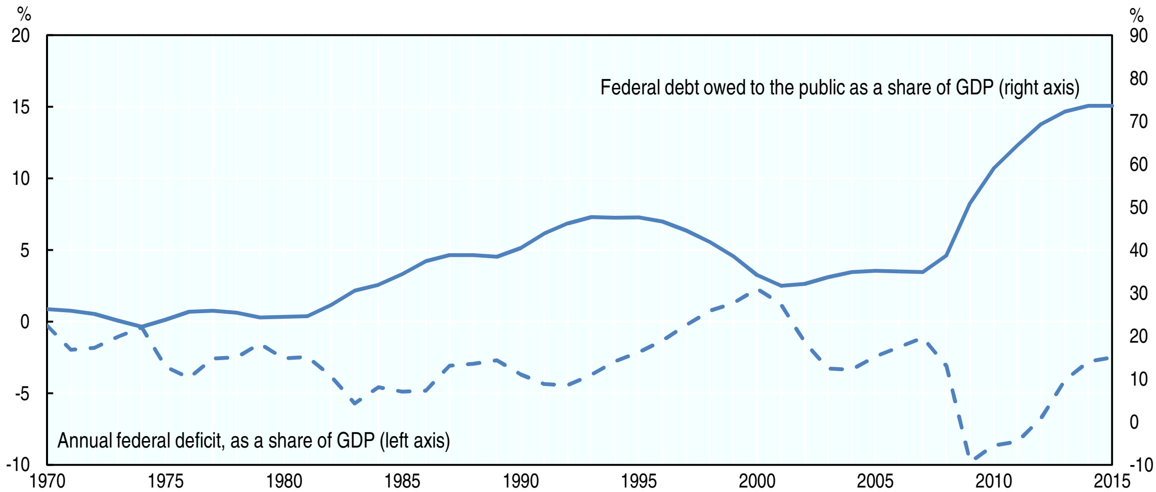


The data are monthly averages of daily data.

Source: St Louis Federal Reserve Bank (2015), Federal Reserve Economic Data (FRED). https://research.stlouisfed.org/fred2/.

StatLink http://dx.doi.org/10.1787/888933408399

Figure 3.5. US Federal deficits and debt as a percentage of GDP, 1970-2015



Source: St Louis Federal Reserve Bank (2015), Federal Reserve Economic Data (FRED). https://research.stlouisfed.org/fred2/.

StatLink http://dx.doi.org/10.1787/888933408404

The recession reduced tax revenues and induced increased federal spending through the actions of automatic stabilisers, and the US government took further fiscal policy actions to stabilise the economy. In consequence, annual federal deficits, which had been just over 1% of GDP in 2007, expanded to 3% in 2008 and nearly 10% in 2009 (Figure 3.5). Deficits remained above 8% of GDP in 2010 and 2011, and have since been steadily reduced, to 2.7% of GDP in 2015, and are expected to stabilise at 2.5% in 2016 and 2017 (OECD, 2016).

Increased deficits led to sharp increases in federal debt owed to the public, which amounted to 39% of GDP in 2008, 7 percentage points above its value in 2001, but which rose to 74% of GDP by 2015 (Figure 3.5). The Congressional Budget Office (CBO) projects that, under current laws governing taxes and spending, the share will rise to 80% in 2022, and will reach over 100% by 2040 (CBO, 2015). The projected 2022-40 growth of federal debt primarily reflects the impacts of an ageing population and growing health care costs on expenditures and annual deficits, which are projected to grow to 6% per year by 2040 under the current structure of taxes and programs. The projected growth also reflects specific macroeconomic assumptions regarding interest rates and real GDP growth. General government net debt reported by the OECD was around 88% of GDP over the period 2013-15, and is expected to reach 90% in 2016 and 2017 (OECD, 2016).

Current macroeconomic policy indicates a tightening of monetary policy and a modest loosening of fiscal policy. CBO baseline projections, based on current laws as of January 2016, indicate that the federal budget deficit will increase to USD 544 billion in 2016 (2.9% of GDP) from USD 439 billion in 2015 (2.5% of GDP). In turn, the CBO projects that outlays will increase by 6.2% and revenues by 3.9%. The agency further estimates that debt held by the public will rise to 76% of GDP in 2016 (CBO, 2015).

The Fed increased its target range for the federal funds interest rate by 0.25% in December 2015, the first increase since 2006. The rate refers to loans of reserves among banks and, as it is the interest rate most immediately affected by Fed actions, is used as a target and communications device by Fed policymakers and market-watchers. At the time of the increase, Federal Reserve policy makers indicated that the increase would be the first in a gradual but steady series of increases intended to return to a more normal range of short run interest rates. However, in the face of continued weakness in key economic indicators, the Fed left the target rate unchanged in early 2016.

Long term real interest rates — that is, rates on securities with maturities in excess of one year, and adjusted for expected inflation — have remained low, relative to their historic values, for well over a decade (Bean et al., 2015). Nominal interest rates on ten-year Treasury bonds have remained below 2.4% over the 3rd and 4th quarters of 2015 (Figure 3.4); inflation expectations, as measured by the difference in yields between ten-year Treasury bonds and ten-year Treasury inflation-indexed securities, were at 1.8%, suggesting that the real inflation-adjusted rates on ten-year Treasury bonds were less than 0.6%. Nominal and real rates have been declining in the United States and around the world for two decades (Council of Economic Advisors, 2015).

Interest rates affect agriculture, especially through land values and equipment purchases. Lower rates imply a greater present value for any future stream of land rents, and should therefore lead to higher land values. Agricultural land values in the United States have risen steadily since 1987, with a pronounced rise in 2004-14 (Nickerson et al., 2012). Rising land values have increased the wealth of farmland owners, including farm operators and non-operator landowners, but also raise the cost of land for new entrants to farming who wish to purchase land.

Lower interest rates also reduce the cost of capital equipment and structures for farmers and their lessors, and therefore induce greater investment in new structures and equipment in agriculture. New capital embodies many innovations, and typically substitutes for labour, so investment in new capital contributes to greater productivity growth and also contributes to shifts of production to larger farms.

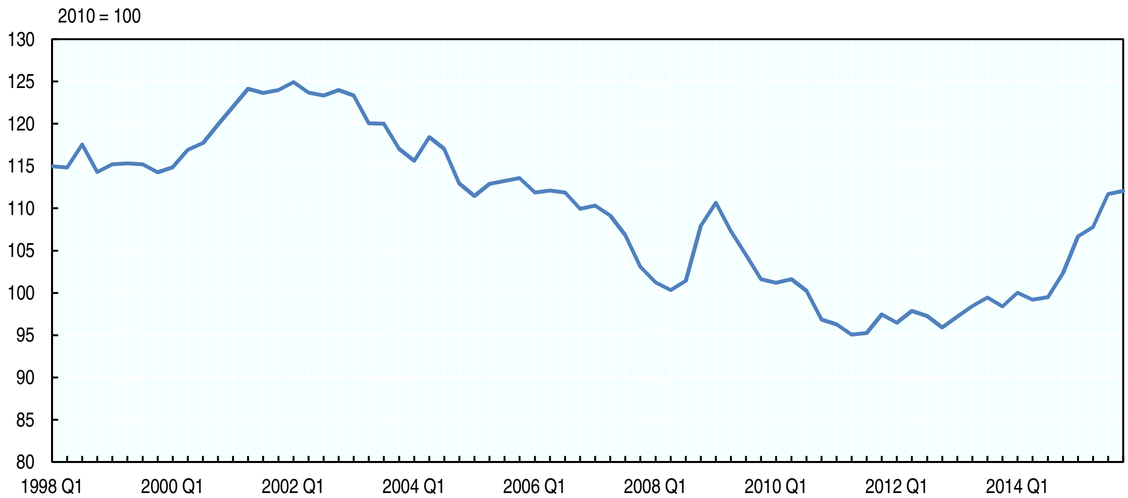
Monetary policy has affected short and long-term rates, but policy is not the sole driver of current low long-term rates. Market forces, in the form of expanded global savings combined with slow growth in industrialised countries, have likely placed separate pressures on rates over time, as have policy decisions that affect national savings. As a result, changes in monetary policy alone are not likely to raise long-term rates back to historic levels.

Currency exchange rates affect the performance of agriculture, because agricultural commodities are prominent in US trade. A high value of the dollar makes US exports more expensive and imports less expensive. In some periods, the effects can be pronounced. For example, in the early 1980s, high real interest rates — a policy choice resulting from a combination of tightening monetary policy and expansive fiscal policy — led to a large and sustained increase in the value of the dollar, and corresponding rise in US export prices. Agricultural exports fell by over a third between 1981 and 1986; with reduced export sales, domestic feed and food grain prices fell by about 40%, triggering substantial increases in commodity programme payments.

Exchange rates respond to international differences in economic growth, inflation, interest rates, and political and financial risks. The value of the US dollar underwent a long depreciation between 2002 and 2008; with a broad agricultural export-weighted index falling by about 20% (Figure 3.6). The US dollar then appreciated sharply during the financial crisis as foreign and domestic capital — seeking safety — flowed into US Treasury securities (increased purchases of US securities imply corresponding transactions for dollars, driving up the value of the dollar). As financial markets recovered, the dollar again depreciated over the next two years. However, the dollar appreciated sharply in the 2nd half of 2014 and through 2015 as financial capital again flowed into US securities in response to slowing growth and perceived financial risks elsewhere in the world (Figure 3.6). Since these conditions are expected to persist and US monetary policy is expected to tighten, the dollar is expected to remain strong in the near term. Sharp exchange rate appreciation has depressed manufacturing activity and export competitiveness (OECD, 2016).

The value of the US dollar rose by 13% between the 3rd quarter of 2014 and the end of 2015 (as measured by the index based on agricultural export weights shown in Figure 3.6). The value of US agricultural exports fell by about 11% in 2015, while the value of agricultural imports rose by about 2%. The agricultural trade balance — net agricultural exports — fell by nearly half from its record high in 2014. The US Department of Agriculture (USDA) expects a relatively strong US dollar to contribute to a smaller agricultural trade surplus than in the next ten years than in the previous decade.

Figure 3.6. The US exchange rate for agriculture, 1998-2015



Bilateral exchanges rates are weighted by US agricultural exports, based on 2008-11 export shares, and converted to an index with a base of 2010.

Source: USDA (2016), Economic Research Service. www.ers.usda.gov/data-products/.

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Productivity growth is sluggish despite the rapid pace of technological innovation. The US Bureau of Labor Statistics estimates that US productivity — measured as net multifactor productivity in the non-farm private business sector — grew at an annual rate of 0.5% per year in 2007-14, after growing by 1.5% per year between 1995 and 2007. That slowdown may largely reflect the effects of the financial crisis and recession, but there is also concern that economy-wide productivity growth may continue to lag in the future. Increases in the educational attainment of the US population have supported past productivity growth, and those increases have slowed (Jorgenson, Ho, and Samuels, 2015). Moreover, some argue that major innovations no longer provide the productivity impact that they once did (Gordon, 2016), and that it will be difficult to again attain the rates of multifactor productivity growth realised in 1995-2007. OECD (2016) points to possible mis-measurement of productivity growth, low business capital expenditure and slower rates of entry and exit, which both drive productivity growth, and a changing composition of the economy shifting towards lower productivity activities in response to ageing population needs or changes in relative prices.

Slower economy-wide productivity growth would likely lower federal revenues and raise federal debt, compared to current projections. The future outlook for debt, and the continuing imbalance between federal revenues and expenditures, will likely constrain future public expenditures on farm commodity, insurance, and conservation programs. The budget outlook may also constrain future public expenditures in support of research and development (R&D), for science in general and for agriculture specifically. Past public support has played a significant role in spurring continued productivity growth in agriculture and in the broader economy.

Governance and the quality of public institutions

Good governance systems and high-quality institutions provide economic actors with the assurance that the government is accountable, transparent, and predictable. They are a fundamental pre-condition both to encourage public and private investment in the economy and to enable those investments to achieve the intended benefits, both for investors and for the country. Moreover, governance systems play an important role in addressing market failure, influencing the behaviour of firms as well as the efficient functioning of input and output markets.

Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction (North, 1990). Economic research has focused on the development of legal and regulatory rules that guarantee private property rights and facilitate the transfer of such rights; that secure such rights for a broad cross-section of society; and that place constraints on the political executive, particularly through the existence of an independent judiciary and a separation of powers among executive, legislative, and judicial branches (Acemoglu, Johnson and Robinson, 2005). Such economic institutions are an important factor in accounting for the very large differences in per capita incomes among countries.

The United States maintains secure property rights for private investment, has an independent judiciary, and constrains the executive. The governance system has been able to address externalities in research and the environment, and to provide for public investment in education and infrastructure over a long period. These and other institutions have contributed to private investment, innovation, and rapid economic growth over 150 years (Gordon, 2016).

Box 3.1. How the US government is organised

There are three levels of government in the United States: federal, state and local.

The **Federal Government** assumes responsibility for national security, foreign affairs, and interstate commerce, and has broad powers of taxation and expenditure in support of the general welfare. Under the Tenth Amendment of the US Constitution, all powers not granted to the federal government are reserved for the states and the people.

All State governments are modelled after the federal government, with executive, legislative, and judicial branches. While State governments share power with the Federal Government in many ways, **local governments** must be granted power by the States.

The Federal Government comprises three independent branches: executive, legislative, and judicial. The executive branch is headed by the President, elected for a four-year term. The legislative branch consists of two houses: members of the Senate are elected for six-year terms, while members of the House of Representatives are elected for two-year terms. Federal judges are nominated by the President to lifetime appointments, and confirmed by the Senate.

The Federal Government has been a primary actor in US agriculture for many years. It administers large federal farm commodity, conservation, and crop insurance programmes; funds and performs agricultural research; administers and regulates agricultural credit programs; manages food safety and agricultural pest and disease programs; and funds food programs.

State governments also play important roles in agriculture. Most agricultural colleges are located at State Universities, and the states independently fund some research and extension activities at universities. States may impose environmental regulations, in addition to federal regulations, on farms. States operate resource conservation programmes, and may form regional compacts with nearby states to attack regional water basin issues. They often engage in joint programmes of agricultural pest and disease control with federal agencies. State Departments of Agriculture administer state-specific promotion, training, and statistical programmes.

In its 2015-16 report, the World Economic Forum (WEF) ranked the United States third among 144 countries in its Global Competiveness Index, which is based on scores calculated from 126 specific items in 12 broad categories (WEF, 2015). Twenty-eight items are based on various statistical indicators like GDP and inflation, while 98 are based on survey responses by business leaders in each country to questions about the business, political, and social environment in their country. There were 369 respondents for the United States, primarily corporate chief executives.

The business leaders ranked the United States high in the categories of "efficiency enhancers" — higher education and training, goods and labour market efficiency, financial market development, and technological readiness. They also gave the country and themselves high marks for innovation and business sophistication. However, the business leaders were far less sanguine about the quality of public governance in the United States.

Sixteen questions on public governance were sorted into five categories: protection of property rights, ethics and corruption in government, undue influence (judicial independence and favouritism in administrative decisions), efficiency of government operations, and security. Business leaders were asked to provide ratings, from 1 (very poor) to 7 (very good) on each of the component questions. Figure 3.7 reports average scores across items in each category for the United States, all OECD countries, and the five OECD countries that received the highest overall quality of governance scores (Finland, New Zealand, Switzerland, Sweden and Netherlands).

The United States scored above the OECD mean in protection of property rights, although below the OECD top five (Figure 3.7). It was close to the OECD average in ethics and corruption, undue influence, and government efficiency, and below the OECD average in security, while scoring below the OECD top five in each.

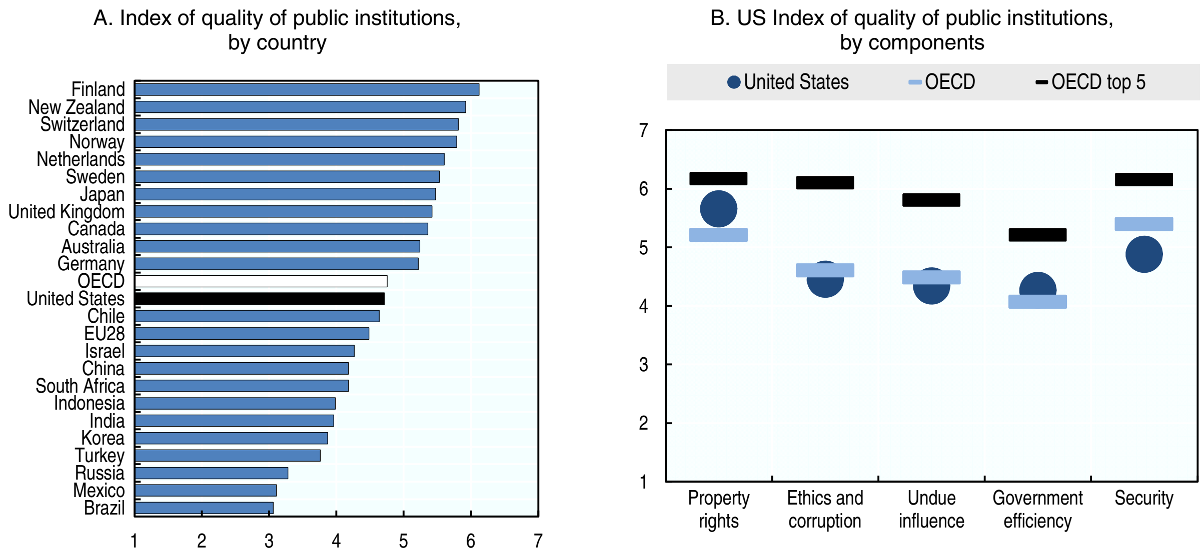
The WEF indexes are largely driven by surveys of business leader opinions of their countries. Surveys of the US population, taken over the last four decades, show substantial declines in Americans' confidence in major institutions (Figure 3.8). In surveys conducted since the mid-1970s, respondents were asked how much confidence they felt in each of a set of institutions, with the choices being "a great deal", "quite a lot", "some", or "very little". The combined values for the top two choices — "a great deal" and "quite a lot" are reported in Figure 3.8 for 1975 and 2015. Substantial declines are reported for each of six institutions — churches, public schools, banks, the Supreme Court, Congress, and the Presidency.

Measures of political polarisation have been growing over the same period that surveys of confidence in institutions show declines (Pew Research Center, 2014). Between 1994 and 2014, the difference in political values between self-described Democrats and Republicans grew substantially wider. In 2014, people of opposing political views expressed much stronger antipathy for those with opposing views than in earlier survey years, and they expressed a stronger willingness to live in communities and associate with like-minded people. Strong political polarisation may be reflected in declining measures of trust in institutions, by the public and by business leaders.

The economic research linking institutions and economic performance focuses on the existence and design of institutions, and their links to long-run economic performance. There is no evidence linking public trust in societal institutions, or the opinions of business leaders concerning their country's public services, to long-run economic performance. Nevertheless, growing political polarisation and eroding faith in institutions may hamper effective public governance systems in the future, and may foreclose the introduction of useful policy innovations affecting sustainable agricultural production.

Figure 3.7. Global Competitiveness Index: Quality of public institutions, 2015-16

Scale 1 to 7 (best)



A. Indices for EU28 and OECD are the simple average of member-country indices.

B. OECD top 5 refers to the average of the scores for the top five performers among OECD countries (Finland, New Zealand, Switzerland, Sweden and Netherlands).

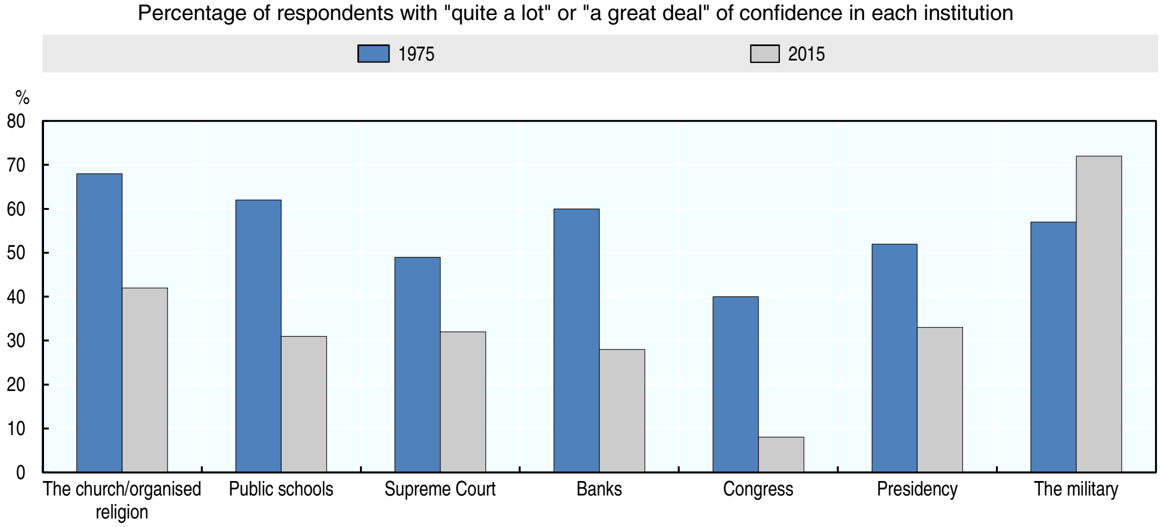
Property rights refer to the average of the indices Property rights and Intellectual property rights. Ethics and corruption refers to the average of the indices: Diversion of public funds, Public trust in politicians and Irregular payments. Undue influence refers to the average of the indices for: Judicial independence and Favouritism in decisions of governmental officials. Government efficiency refers to the average of the indices for Wastefulness of government spending, Burden of government regulation, Efficiency of legal framework in settling disputes, Efficiency of legal framework in challenging regulations and Transparency of government policymaking. Security refers to the average of the indices for: Business costs of terrorism, Business costs of crime and violence, Organised crime and Reliability of police services.

Source: World Economic Forum (2015), *The Global Competitiveness Report 2015-2016,* www.weforum.org/reports/global-competitiveness-report-2015.

StatLink http://dx.doi.org/10.1787/888933408428

Figure 3.8. Americans report declining trust in most institutions, 1975 and 2015

Percentage of respondents with "quite a lot" or "a great deal" of confidence in each institution



Source: Gallup Organisation (2016), *Trust in Institutions*, www.gallup.com/poll/1597/confidence-institutions.aspx.

StatLink http://dx.doi.org/10.1787/888933408433

Summary

- The United States is a large, leading and wealthy economy, with well-developed institutions to manage economic policies.
- The US economy was hard hit by the recession and financial crisis of 2007-09, but the government took action to reduce financial risk and restore short and long-term credit for economic activities, and stabilise the economy. In addition, the Fed took step to reduce long-term interest rates. At the same time, inflation remained moderate.
- Recovery from the recession occurred slowly, as sharp reduction in household wealth led to reduced consumption expenditure. Since 2010 GDP enjoys moderate annual growth slightly above 2%. Federal deficits which had increased sharply have been steadily reduce to 2.5% of GDP in 2015, but debt as a percentage of GDP remains high (74% in 2015).
- Low interest rates affect agriculture, especially by raising land value and facilitating equipment purchase. Investment in capital embodies many innovations. Changes in exchange rates have also affected the performance of US agricultural exports.
- Governance responsibilities are shared between federal, state and local governments.
- The United States maintains secure property rights for private investment and has an independent judiciary system. Business leaders rank US institutions close to OECD average, although security is a concern for them. Surveys of US population indicate a declining trust in institutions and growing political polarisation, which could hamper the introduction of new policies.

Note

1. General government shows the consolidated (i.e. with intra-government amounts netted out) accounts for all levels of government (central plus state and local). This measure is not the same as federal debt held by the public, which is typically reported in US budget analysis (OECD, 2016) and used in this chapter.

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Chapter 4

INVESTMENT IN THE US FOOD AND AGRICULTURE SYSTEM

This chapter reviews general incentives for investment decisions by US farms and agribusinesses. Those decisions affect the development and diffusion of innovations, the pace of productivity growth, and the sustainability of food production. They are in turn affected by a range of government regulatory policies, which can encourage or deter investments. While some US regulations are state-specific, most regulatory policies covered in this chapter are federal, and apply across all states. Some are general, covering all firms in the economy, while important elements of others are specific to agriculture. The chapter starts with the overall regulatory environment as it focuses on the behaviour of firms and farms, and surveys broad-based policy regarding taxes, finance, and international trade and investment.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Regulatory environment

The overall regulatory environment establishes basic conditions within which all firms, including farms, input suppliers, and food companies operate and make investment decisions. Competitive conditions in domestic markets, including low barriers to entry and exit, can encourage innovation and productivity growth, including through their impact on structural change. Regulations may also enable or impede knowledge and technology transfer directly, contributing to more or less innovation, including in sustainability-enhancing technologies.

The regulatory environment in agriculture encompasses three major areas: the regulatory environment for entrepreneurship, including the ease of entry by new businesses, and the role of competition policy in furthering innovation and adaptation to new market conditions; regulations on the use of natural resources, with a particular focus on agriculture; and regulations concerning products and practices that affect animal, plant, and human health in agriculture, including the control of animal and plant pests and disease, biotechnology, and animal drugs.

Regulatory environment for entrepreneurship

The environment for entrepreneurship refers in part to government regulations and programmes that affect the ease with which new firms can start and grow, which in turn can affect the pace with which new innovations can spread through the economy. It also refers to competition policies, including antitrust policies, which aim to protect economic freedom and opportunity by promoting free and fair competition in markets.

The United States relies heavily on competition, and less on government intervention in markets, to guide production decisions in the economy. This is borne out by inspection of OECD indexes for Product Market Regulation (PMR) (Koske et al., 2015; OECD, 2015). The PMR indexes tell a striking story (Figure 4.1.A). The United States had the second least restrictive set of PMRs in 2008 (no US data were reported for 2013), reflecting both an historical emphasis on competition in markets, and a shift in the 1970s and 1980s away from existing PMRs. However, PMRs in each of the 15 OECD countries have become less restrictive over time, as countries have shifted away from using product market regulations to realise social goals. Two countries — the Netherlands and the United Kingdom — had lower values of the index (i.e. less restrictive PMRs) in 2013 than the US value in 2008.

Box 4.1. Restrictions on entry and exit in agriculture

With a few exceptions, US agricultural policy places few restrictions on entry, exit, production, and structural adjustment in farming. The sugar programme does retain marketing allotments for processors that limit how much sugar can be marketed domestically in a given year. However, the allotments have not been binding in recent years. In addition, marketing orders for ten commodities — almonds, dates, hazelnuts, prunes, raisins, walnuts, tart cherries, Florida citrus, cranberries, and spearmint oil — retain volume control options. Marketing orders, once approved by producers and the Secretary of Agriculture, are binding on producers in a specified geographic region. They function as a collective device for supporting marketing and research expenditures, for setting quality standards, for standardising packaging and containers, and for regulating the flow of products to markets. They may also have authority to set volume controls, so as to affect prices and grower returns.

Supply controls were more widely applied in the past. Today, volume controls in marketing orders are only active for tart cherries. In addition, the Secretary of Agriculture retained, and sometimes used, his authority to impose supply controls on wheat and feed grains, in the form of acreage reduction programmes and annual acreage set-asides, under laws that go back to the 1930s. However, commodity programmes moved away from supply controls over time, and the authority was revoked in the 1996 farm bill (the Federal Agricultural Improvement and Reform Act).

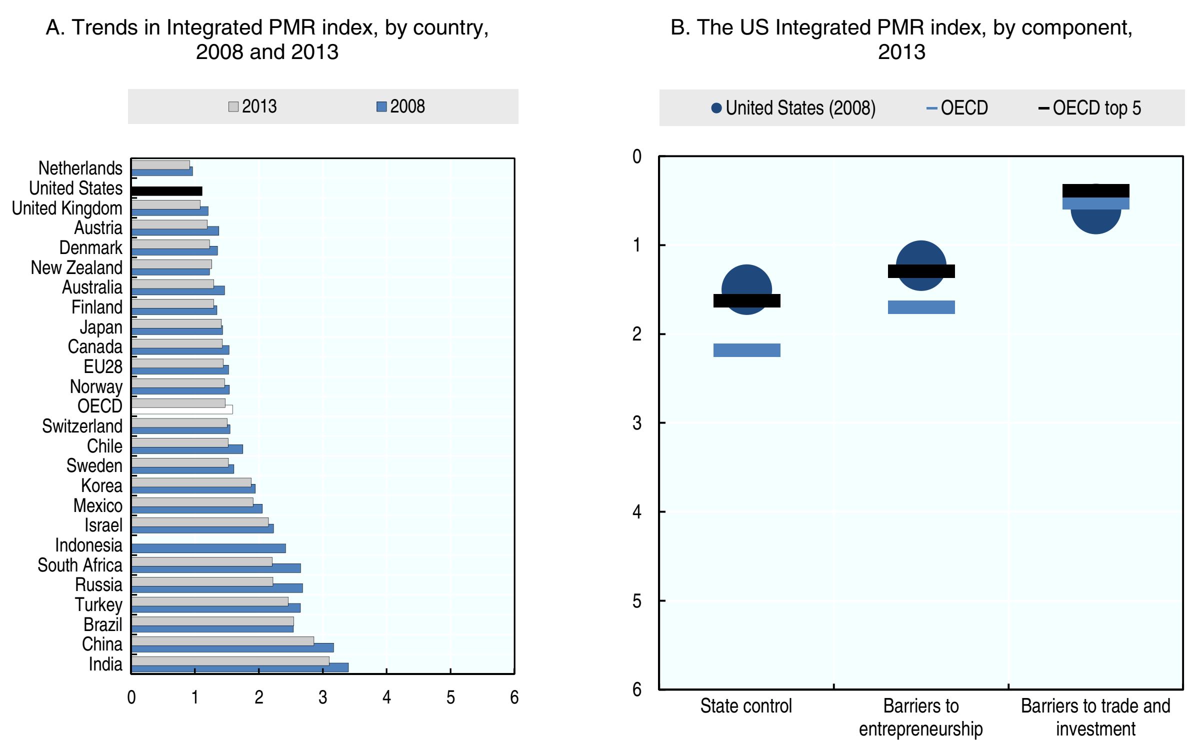
Federal peanut and tobacco programmes relied on marketing quotas to regulate production and to support prices paid to producers. Quota rights were valuable, but the transfer of the rights among farmers was restricted to narrow geographic areas. After the programmes were terminated in the early 2000s, production shifted rapidly to different geographic areas and consolidated onto larger farms (Dohlman et al., 2009; Kirwan et al., 2012). The rapid structural changes indicated that policy had previously restricted adjustment in those industries.

The indexes include a range of components. Compared to OECD averages, the United States was considerably less reliant on state control or public ownership of industries in 2008, ranking 2nd lowest of the 34 OECD countries in each (Figure 4.1.B). There is effectively no state ownership of commercial farms in the country, and virtually no state ownership of food processing firms. Publically owned water, electric, and telephone utilities provide services to farmers, especially in rural areas (Section 5.1).

The United States also ranks second lowest among OECD countries in overall barriers to entrepreneurship, according to the PMR indicators (Figure 4.1.A). In three key components — legal barriers to starting a business, administrative burdens on corporations, and administrative burdens on start-ups — the United States has lower barriers or burdens than the OECD average, but it does place relatively higher burdens on start-ups than on incumbents (Figure 4.2).

Figure 4.1. OECD Integrated Product Market Regulation (PMR) Indicator, 2008 and 2013

Scale from 0 (least) to 6 (most) restrictive



OECD top 5 refers to the average of the scores for the top five performers among OECD countries (Netherlands, United Kingdom, United States, Austria and Denmark), with US data referring to 2008.

Indices for EU28 and OECD are the simple average of member-country indices.

OECD Product Market Regulation (PMR) indicators measure key regulations in the areas of state control, barriers to entrepreneurship, and barriers to trade and investment.

Source: OECD (2014) Product Market Regulation Database. www.oecd.org/economy/pmr.

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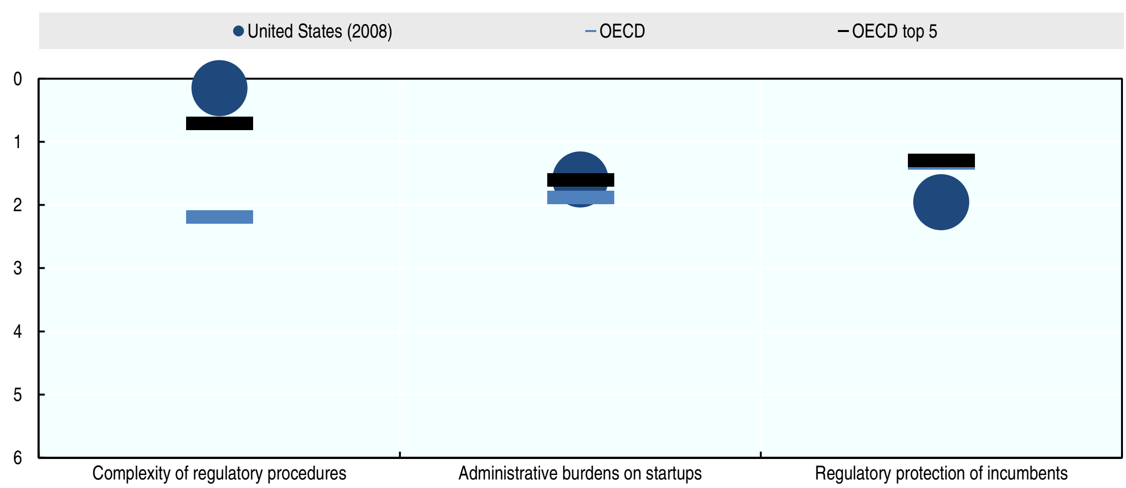
The antitrust laws in the United States are broadly applied across the economy, except for a few industries with explicit exemptions. The laws, primarily the Sherman Antitrust Act (1890) and the Clayton Act (1914, significantly amended in 1936 and 1950) are enforced by the Antitrust Division of the Department of Justice (DOJ) and by the Federal Trade Commission (FTC), an independent regulatory agency. Enforcement focuses on collusion among competitors (to fix prices or allocate markets), mergers that might lessen competition, and predatory or exclusionary business practices that might allow firms to acquire or retain monopoly power.

The Packers and Stockyards Act (1921) focuses on business practices in livestock industries, and is enforced by the Grain Inspection, Packers and Stockyards Administration (GIPSA) of USDA. The Act deals with practices deemed to be deceptive and unfair, as well as certain practices that violate antitrust laws by restraining competition. The antitrust provisions of the Act appear to some to cover a broader set of practices and injuries to producers than are generally covered under antitrust statutes, but US courts have interpreted the Act in line with other antitrust laws, and have required evidence of a practice's injury to competition, in the form of effects on production and market prices, to support allegations of a violation of the Act (Hovenkamp, 2011).

Figure 4.2. Barriers to entrepreneurship indicator, by regulatory area, 2013

Scale from 0 (least) to 6 (most) restrictive



Indices for OECD all are the simple average of member-country indices.

OECD top 5 refers to the average of the scores for the top five performers among OECD countries (Slovak Republic, New Zealand, Netherlands, Italy and United States), with US data referring to 2008.

Source: OECD (2014) Product Market Regulation Database, www.oecd.org/economy/pmr.

StatLink http://dx.doi.org/10.1787/888933408456

Antitrust policy proceeds on the presumption that competition benefits consumers through lower prices, better quality, and wider choice, and that it supports innovations, productivity growth, and opportunities for businesses. However, US antitrust policy does not focus on maintaining or achieving market structure goals, on the grounds that market structure alone is not a sufficient indicator of competition. Instead, it can be argued that the main concern of US antitrust lies in restraints on output, and output can be measured in terms of production or innovation (Hovenkamp, 2005). A restraint on production, such as that created by a sellers' cartel, forces prices up while a restraint on innovation forces customers to accept inferior goods, services, or methods of distribution.

In the late 1990s, international price fixing cartels in three products used as agricultural inputs — lysine, vitamins, and citric acid — were uncovered. This led to legal actions, resulting in severe penalties. This and other experiences revealed that cartels could last for periods up to a decade, that they tended to occur in markets for homogeneous products with a small number of sellers, and that they could have significant effects on prices.

Explicit collusion (agreements among rivals to fix prices or market shares) is a *per se* violation of the antitrust laws, meaning that the act itself is a violation, without regard to its economic effects. Collusion is a criminal offense, and the DOJ has sought and obtained jail terms in some major cases, as well as substantial fines.

However, mergers and other business practices are approached on a case-by-case basis, with a substantial application of economic and legal theory, and fact-based evidence. They are evaluated for their likely effect on output, innovation, and ultimately prices in markets. Mergers or practices that are likely to lead to reduced output or higher product prices are said to damage competition, and antitrust agencies are likely to oppose them.

In agribusiness, seeds, agricultural chemicals, and railroad transportation tend to be highly concentrated, with few sellers in relevant markets. Specific concerns in agriculture also relate to monopsony power exercised by commodity buyers. The most well-known issues concern meatpacking, where in most markets producers of fed cattle, pigs, or poultry sell their goods and services to a small number (one to three) of processors. In cases of monopsony, the antitrust concern is with mergers or business practices that might lead to restraints on market purchases, and lower prices for sellers. The issue of concentration in agriculture attracts widespread attention, including a series of hearings held by the DOJ and USDA in 2010.

However, high concentration does not necessarily lead to the exercise of market power, in the form of restraints on output that lead to lower prices paid to farmers or higher prices charged to them for inputs. High concentration that results from the exploitation of scale economies and cost reductions can lead to increased production, and therefore increased demand for the farm products that are used in production.

The Economic Research Services of the USDA has recently published a review of the theoretical and empirical impacts of increased concentration and segmentation in US agricultural markets (Adjemian et al., 2016). Most research finds that increased concentration has had negligible price impact. High concentration has been reinforced by segmentation and vertical coordination (including contracting), potentially leading to lack of transparency in thinner markets that complicates the design, monitoring and evaluation of policies pursuing price and income objectives. Suggestions are made to establish a common contracting format in each market in order to reduce transactions costs and improve the participation of small producers; to improve data collection on prices and quantities; and provide production and marketing advice to producers through public extension services.

For storable commodities with multiple uses — such as grain and oilseed crops — farmers can ship to multiple buyers in different industries and at different times, and markets remain quite competitive. In some industries, such as dairy and pork, farmer cooperatives have limited the potential market power of processors, by bargaining and sometimes by entering processing on behalf of their members. Over longer periods of time, farmers can change the commodities that they produce, which limits the pricing power of concentrated commodity buyers. A firm's ability to exercise market power depends only in part on concentration in a market.

When evaluating whether a merger of rivals might reduce competition, US antitrust agencies focus on the level of market concentration before and after the merger, the extent of barriers to entry into the market, and the extent of price competition from differentiated rival products. In practice, the agencies have tended to oppose mergers between competitors in highly concentrated agricultural markets, such as the purchase of National Beef Packing by JBS Swift in 2008, which would have reduced the number of fed cattle buyers from three to two in many markets, and from two to one in others. Mergers that leave four or more competitors active in a market are much less likely to be opposed (Kwoka, 2015).

Some argue that merger policy should be more aggressive against mergers between competitors in concentrated industries (Kwoka, 2015). However, anti-trust authorities face severe difficulties in pursuing a more aggressive antitrust policy in part because they must make a legal case against mergers in non-specialist courts and bear the burden of proof against well-funded firms with plenty of lawyers (OECD, 2016a).

The 1922 Capper-Volstead Act grants certain agricultural cooperatives limited immunity from the antitrust laws, permitting their members to jointly process, prepare for market, handle, and market their commodities, and to jointly purchase inputs. Proponents of the Act viewed cooperatives as important bulwarks for farmers against monopsony power exercised by processors and other market intermediaries. Exemptions concern activities related to marketing, not activities that restrict output.

Currently, some cooperatives face allegations that they have taken actions to limit production and raise prices. Private lawsuits alleging such behaviour have been filed in the egg, potato, and milk industries. Historically, antitrust agencies have taken the position that the Capper-Volstead Act does not exempt production limits from the antitrust laws (Varney, 2010). The issues at hand then come down to questions of economic theory and evidence — whether cooperatives have the power to effectively restrict market output, and whether they have in fact done so.

Regulations on natural resources

General environmental regulations

Regulations on the environment and natural resources are central to ensuring the long term sustainable use of natural resources and in large part determine access to and use of land, water and biodiversity resources. Regulations on natural resources impose rules on industrial and agricultural activities in order to protect the state of the natural resource (e.g. water pollution, soil degradation, greenhouse gas emissions). Environmental quality has the attributes of a public good, which can make it unprofitable for the private sector to provide, even when the benefits to the public exceed the costs of provision. The design of natural resources and environmental policies is important in terms of their incentives for innovation and sustainable productivity growth.

Other environmental regulations, less specific to agriculture also apply to the agricultural sector and include among others: regulations on oil storage and use, on hazardous substances, on buildings, constructions and renovations, and on waste management.

The States have their own environmental and natural resource regulations, and they sometimes have enforcement responsibilities for federal (EPA) regulations. In particular, land and water rights are mostly regulated at the State level and vary by State depending on resource availability and pressure. Land zoning is also set and managed at the state level, with Eastern States being more likely to have programmes to deal with land development rights. Zoning generally limits farmland being used for development. Box 4.2 provides an illustration of state regulations in the case of water for California, Florida, and the Chesapeake Bay. Box 4.3 outlines the water scarcity challenges in the South Central Valley, California.

Box 4.2. Water regulation: Illustration of the role of states in the case of water quality management in Chesapeake Bay and of groundwater management

Water quality and ecosystem restoration in the Chesapeake Bay

The Chesapeake Bay suffers from problems of water quality, degraded habitats and reduced population of shellfish, mainly due to nitrogen and phosphorus pollution. Agriculture is the largest source of nutrient emissions in the Bay, arising from fertiliser use, livestock manure and certain cropping practices. To meet this challenge, a strategy for restoring the Bay was released in 2010. As part of this strategy, for each water body impaired by pollution, a Total Maximum Daily Load (TMDL) has been established. TMDL is set at the state level or, by default, by the EPA. To comply with TMDL, implementation measures should be put in place by 2025. States of the Watershed (Virginia, Maryland, West Virginia, Delaware, Pennsylvania, and District of Columbia) have prepared Watershed Implementation Plans (Phase 1) to meet the standard in place in 2017.

Groundwater regulation

The States have "primary responsibility for the design and implementation of groundwater withdrawal policies on private and State-owned land — including most lands used for agricultural crop production" (OECD, 2015c). This means that regulations differ across states, for example: groundwater management plans are mandatory in some states (especially in the Northern High Plains and the Mountain and Pacific Regions) but voluntary in other states. Differences in groundwater regulations across states also include: regulation on irrigated areas; on expansion of agricultural lands; regulations on groundwater withdrawals and restrictions. In addition to these differences in regulatory approaches, the states. Besides these differences in regulatory approaches, States also develop their own specific policy packages using tools such as economic instruments and collective management approaches.

Source: Adapted from US Congressional Research Service (2014) and from OECD (2015c).

Box 4.3. The South Central Valley in California continues to face water scarcity

In the mid-19th century the southern part of California's "Central Valley" contained several natural lakes, notably Tulare Lake covering 450 to 800 square miles; the San Joaquin River was large, though shallow, and formed the basis of the early transport system in the valley. In the 21st century not only do long sections of the San Joaquin river and its tributaries frequently run dry, but Lake Tulare has been dry for several decades, except after rare extreme precipitation or snowmelt. Other rivers, too, are mostly dry except where used as part of the canal system. Average annual water extraction now exceeds average annual water supply

After several years of drought, many inhabitants of East Porterville, about five miles from Lake Success, an important storage dam on the Tule River, relied on water delivered in road tankers, or bottled water. Their wells had run dry as the water table dropped, and most of the town has no piped water (unlike its contiguous neighbour, West Porterville). Waters near the mouth of the San Joaquin suffer from excess nutrient problems and some increase in salinity. Fish stocks are much reduced, although still significant in the lower reaches of the river system. Commercial river fishing for Chinook salmon ended in 1957.

Water supply comes from local rain in the valley itself, but more importantly from precipitation in the neighbouring mountains, mostly stored in the snowpack. Dams retain nearly all river inflows, which are highly seasonal, when or before they reach the valley, for distribution through an extensive set of canals.

Agriculture represents a major pressure on water resources in a context of insufficient regulation of groundwater

Land in the Central Valley is particularly fertile, provided there is enough water for crops. California supplies around 8% of US agricultural output, much of this in south Central valley. It is very flexible, adjusting to changes in demand, for example supplying nearly 100% of the fast growing US demand for almonds as well as exporting abroad. In the recent drought, although much land lay fallow for lack of irrigation water, average farm incomes were rising and farmers were increasing their planting of almond trees (OECD, 2015c).

When the dams run low in dry years, farmers make up the difference by pumping more groundwater, with net recharge of the groundwater occurring in wet years. However, on average, over a series of wet and dry years, farmers use more water than is supplied from precipitation (sometimes twice as much), hence the falling water table and other phenomena described above. The effects have been extreme during the 2012-15 droughts, partly because the droughts were severe and the weather warm, and partly because agricultural water use is increasing and groundwater supplies already overstretched.

Pumping groundwater was until very recently largely untouched by direct state regulation in California, as state law allows landholders to pump any amount of groundwater below their property, unlike some other states such as Kansas and Texas, where it is regulated in various ways. There is not always a simple free-for-all, however, as past conflicts between competing users have led to court cases under which quasi-collective management develops under a court-appointed Water Master (Cooley et al., 2009). It is not clear that such arrangements restore sustainable use of groundwater. According to Cooley et al. (2009) there were 19 adjudicated water basins in California, most of them in Southern California (i.e. not in Central Valley).

The resource rent is thus entirely absorbed within the agricultural industry and the lack of regulation may imply that water is used in agriculture which could be better used for some alternative activity. Grismer (2001) estimated the value of water used for one South Central Valley crop in the 1990s to have been between USD 150 and USD 240 per acre-foot, depending on the county, "considerably less than [the price] paid by municipalities" (Grismer, 2001). A significant part of agricultural production in the area is clearly due to the running down of groundwater stocks, and therefore eventually unsustainable.

Policy challenges and responses to sustainable water management in the South Central Valley

Groundwater is the archetypal "tragedy of the commons" (Coman, 1911). Except in rare cases where there is no link at all between a local aquifer and adjacent groundwater levels, each farmer's use of groundwater reduces the supply of water for neighbouring farms, but no-one has an incentive to take this into account. The situation will become even less sustainable if climate change confirms the expected reduction in water storage capacity in the snowpack, so that dam capacity will become even less adequate and reliance on pumped groundwater increase. Yet the observation that farmers were planting more (thirsty) almond trees in the middle of the recent drought suggests that this is not being taken into account.

To achieve sustainability before the point of economic exhaustion is reached, OECD (2015c) provides some guidelines for successful management, noting six key conditions, that need to be built into a mix of economic, regulatory and collective action approaches:

- build and maintain sufficient knowledge of groundwater resource and use
- manage surface and groundwater conjunctively (together) where relevant
- favour instruments that directly target groundwater use over indirect measures (e.g. land use regulation), where possible
- prioritise demand–side approaches
- enhance the enforcement of regulatory measures (e.g. water entitlements) before moving to other approaches
- avoid non-water related price distorting policy measures, such as subsidies towards water intensive crops and energy, which could affect groundwater use.

There have been attempts to improve groundwater management, for example the Central Valley Project Improvement Act of 1992, but they have often foundered on the difficult problem of changing property rights in water as well as the fact that active groundwater management in California, and especially in Central Valley, where adjudicated basins are rare, was largely voluntary (Moran and Cravens, 2015). Most water districts do have a groundwater management plan, but they have rested on voluntary cooperation and, although loss of groundwater slowed down overall prior to the recent drought, it had not generally stopped and losses during the recent drought have been large.

In 2014, California adopted the Sustainable Groundwater Management Act of 2014 (SGMA). The SGMA mandates local water authorities to adopt sustainability plans by 2020 (or 2022 for less severely stressed areas), with a view to actually achieving sustainability by 2040. The major advance on previous programmes is that the SGMA gives the state the power to intervene and impose a sustainability plan if the local agency does not or if its plan is not adequate. It is also a good example of the "tripod" approach combining a mix of economic, regulatory and collective action approaches (OECD, 2015c).

The SGMA may be very slow-acting, however because some key issues remain to be clarified. The first issue is simply what constitutes a local water authority (known as a Groundwater Sustainability Agency, GSA) responsible for setting up and implementing the plans. In most places there is as yet no such body; the Act invites potential agencies to propose themselves as GSAs, after which negotiation or arbitration will sort out competing or overlapping claims to jurisdiction.

The second issue for the SGMA is to clarify what constitutes sustainability. The Act takes a common sense approach in defining it as avoiding "undesirable results" defined as "significant and unreasonable" results in specific dimensions such as lowering of groundwater levels, depletion of surface water, degraded water quality and subsidence. On any of these criteria the situation in South Central Valley is unsustainable. But as Moran and Cravens (2015) points out, there is nevertheless room for disagreement on what is "significant and unreasonable" so that litigation on specific future measures is quite likely. The fact that "not a single legislator from the San Joaquin Valley voted in favour of [the SGMA]" (Green et al., 2015) may presage some of the difficulties.

Additionally, there are potential coordination problems: the legislation does not grant GSAs permitting authority for the construction, modification or abandonment of groundwater wells; rather this authority remains the jurisdiction of local government agencies. Close coordination between GSAs and permitting agencies will therefore be essential in order to ensure that groundwater sustainability goals are consistent with the well permitting and land use actions of the local government agencies (Moran and Cravens, 2015). These potential problems will be compounded by the system of entitlements to water use in California, which does not define clear property rights in water but in practice often gives strong precedence to prior use of water.

If the SGMA leads to clearer definitions of property rights and effective monitoring of water use, extraction of groundwater, and the state of groundwater reserves themselves, use of market mechanisms could increase the efficiency of water allocation (Aladjem and Sunding, 2015). A homogeneous market with a single price for groundwater is unlikely to develop – the externalities associated with pumping water can vary from place to place. But price signals could nevertheless help to better negotiate various trade-offs, between agriculture, industrial and household water use, as well as between these and environmental services.

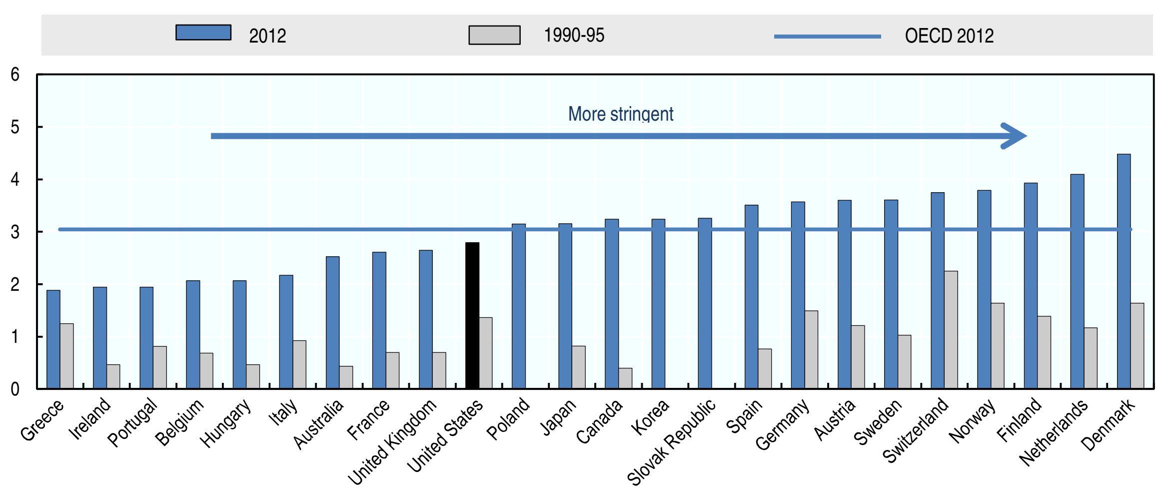
The SGMA also mandates better collection of data on stocks and flows of groundwater. Together with better information on willingness-to-pay for water, this information can help to make better decisions on infrastructure. According to PPIC (2015), in addition to the problem of water shortage for droughts, infrastructure finance, provision of safe and affordable drinking water in some communities, and funding for ecosystem management programmes are all "fiscal orphans" with more resources required but responsibility and the assessment of costs and benefits unclear.

Stringency of environmental regulations

Overall the stringency of environmental policy, as measured by the OECD index, has increased since the 1990s, in the United States as in other OECD countries (Figure 4.3). US environmental policy remained, however, less stringent than on average in OECD countries in 2012. In comparison with large countries with low population density, environmental policy is less stringent than in Canada, but more than in Australia. It is also lower than in Japan and countries of Northern Europe, but higher than in France and the United Kingdom. This indicator, however, is not disaggregated by economic sector, so it is important not to extrapolate these results to the agricultural sector, which requires more specific investigation.

Figure 4.3. Stringency of environmental policy, 1990-95 and 2012

Index scale from 0 (least restrictive) to 6 (most stringent)



Source: Botta, E. and T. Koźluk (2014), http://dx.doi.org/10.1787/5jxrjnc45gvg-en.

StatLink http://dx.doi.org/10.1787/888933408463

Farming practices and the environment

As discussed in Chapter 2, some farming practices can degrade resources and the environment in the United States, such as: sediment, nutrient, and pesticide runoff and leaching that can impair water quality, either in surface waters or in groundwater.[1] Excessive nutrients can create algae blooms that affect the colour and taste of drinking water, as well as nitrate concentrations that can affect human health; runoff of nutrients and pesticides can also affect aquatic life in streams, lakes, and estuaries. Agriculture also accounts for 9% of national greenhouse gas emissions through fertiliser application, certain soil management practices, and livestock (methane emissions).

Some agri-environmental programmes provide financial incentives to adopt various conservation practices (voluntary programmes), while others tie eligibility for agricultural commodity and insurance programmes to compliance with certain conservation practices (mandatory programmes). Chapter 6 provides an overview of these programmes, and their relative importance over time. There are five main voluntary conservation programmes, which include both land retirement and programmes on working farmland, including agricultural land preservation and adoption of environmentally friendly production practices. They are presented in Box 6.3, while Box 6.2 presents changes in mandatory compliance since the 1996 Farm Bill.

This reliance on incentives over direct regulation follow in part from the structure of the farm sector: direct regulation would be quite costly in a sector with over 2 million farms. It also follows from the nature of farming, where a farm's impact on the environment depends on many different decisions at farms as well as the specifics of the natural environment that any particular farm operates in, and regulators cannot easily observe those decisions.

In the United States, there are some environmental regulations concerning agriculture at the federal level. These regulations include, in particular: 1) regulation on Concentrated Animal Feeding Operations (CAFOs); and 2) regulations on pesticides.[2] The Clean Water Act has an impact on private land as it prevents landowners from draining wetland, but its impact on farmland is limited. The agricultural sector is generally excluded from the scope of federal regulations on greenhouse gas (GHG) emissions, notably with regard to mandatory reporting of GHG (Greenhouse Gas Reporting Rule)[3] and to permitting requirements for stationary sources of air pollutants, such as livestock operations.

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) constitutes the regulatory framework for the sale and use of pesticide products, with the objective to prevent health and environmental risks.[4] All pesticides should be licensed by the Environmental Protection Agency (EPA), and types of allowed uses and restrictions should be indicated. About 600 pesticides are currently registered for use in food production in the United States. Pesticides should follow a re-registration process every 15 years on the basis of updated regulatory rules and scientific methods. However, the chemical runoff from fields that can degrade the environment is a nonpoint source of pollution, which is quite difficult to regulate directly. USDA aims to limit the environmental risks associated with use of approved pesticides, by implementing financial incentive, compliance and information programmes.

Regulations on Concentrated Animal Feeding Operations (CAFOs)

Manure contains valuable crop nutrients. However, over-application of manure to fields can create water pollution through run-off to surface waters, and may also contaminate ground-water. Manure storage and transportation carries risks of spills, which also may lead to water pollution, and volatilisation of stored manure may lead to air pollution. Some farms have been designated as point sources of manure effluents and are under direct regulation of production and manure management practices.

Specifically, the EPA regulates production practices at certain livestock operations under provisions of the 1972 Clean Water Act. The EPA "CAFO" regulations require farms to seek permit coverage under the National Pollutant Discharge Elimination System (NPDES) if they have been designated as a concentrated animal feeding operation (CAFO), and are discharging — or proposing to discharge — manure effluent. In turn, a permitted CAFO must have a Comprehensive Nutrient Management Plan (CNMP) that identifies site-specific practices to ensure agronomic use of nutrients. CAFOs that are not required to have an NPDES permit, but that wish to claim an agricultural stormwater exemption from the Clean Water Act for runoff from fields receiving manure, must also have a nutrient management plan.

CAFOs are defined according to three criteria — the quantity of manure produced on the operation, whether manure is discharged to surface water, and whether the farm is significant contributor of pollutants. The quantity of manure criterion is defined according to the number of animals onsite (for example, operations with at least 700 mature dairy cows, 2 500 feeder pigs, or

125 000 broilers are defined as large CAFOs). Medium CAFOs are smaller (for example, 200-699 mature dairy cattle, or 750-2 499 feeder pigs) and have man-made conveyances that discharge animal waste to waters, or the animals come into contact with surface water while confined. Small CAFO's fall below the medium size threshold but have been designated by the permitting authority as a significant contributor of pollutants.

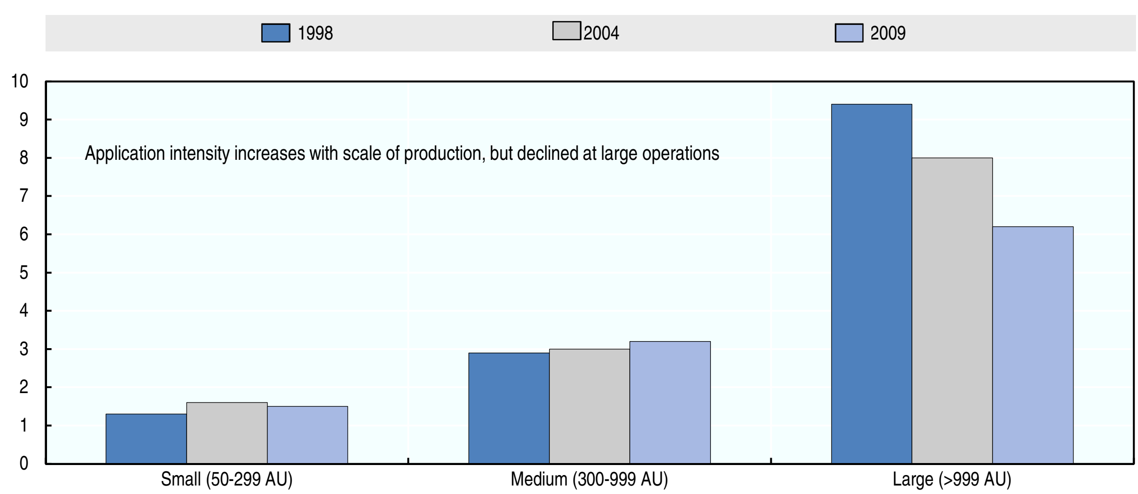
The EPA develops CAFO standards, but enforcement is carried out by individual States, which have adopted the new rules at varying rates. States may also have specific environmental regulations affecting livestock operations. USDA's Natural Resources Conservation Service provides technical assistance in developing CNMPs, and also administers programmes, like the EQIP, that assist producers in developing structures or practices to improve manure management and comply with nutrient management plans.

Livestock production has shifted steadily toward much larger operations (Table 2.3), with particularly rapid consolidation in dairy and pig production (MacDonald and McBride, 2009; MacDonald, Korb, and Hoppe, 2013). The EPA estimates that 18 651 operations were CAFOs in 2014.

Consolidation of production also concentrates manure in fewer locations, but regulations appear to have an impact on manure management practices among larger operations. For example, larger US pig operations produce considerably more manure, per acre of land to which manure is applied, than smaller operations (Key et al., 2011). However, the average application rate among large operations was cut by about one-third between 1998 and 2009 (Figure 4.4).

Figure 4.4. Manure application intensity in pig production, 1998, 2004 and 2009

Animal units (AU) per acre of manure applied



One animal unit (AU) is equal to 1 000 pounds of live weight production.

Source: Key et al. (2011). www.ers.usda.gov/publications/eib-economic-information-bulletin/eib81.aspx.

StatLink http://dx.doi.org/10.1787/888933408474

In broiler production, operations in sensitive areas near major estuaries and river basins are likely to have nutrient management plans. Farms without nutrient management plans have substantially higher litter application rates than farms with such plans; moreover, application rates — defined as the number of birds produced, per acre of land to which litter was applied — fell among operations with plans between 2006 and 2011, while rising at operations without such plans (MacDonald, 2014).

Farms can adjust their practices to meet the regulations in several ways, including the use of manure application methods — such as injection into the soil — that limit runoff, spreading manure over more cropland acres, and adjusting feed rations to reduce nutrients in manure. Farms can also remove manure from the operation, typically to crop farms, and removals from pig and from broiler operations increased in the 2000s (Key et al., 2011; MacDonald, 2014). However, manure application rates at crop farms are not federally regulated (although some states apply manure application rules to crop farms).

Federal CAFO rules effectively establish size thresholds for regulations, with larger farms facing greater regulatory stringency. Farms make investment decisions with those thresholds in mind (Sneeringer and Key, 2011). After the 2003 introduction of size-based thresholds, newly constructed pig operations clustered just below the size threshold for regulation, thus avoiding more stringent regulation. The avoidance actions, which covered 7-11% of potentially regulated new entrants, suggest that regulation has had an impact on manure management and costs at regulated operations.

Regulations on products and processes

Regulations on products and processes that aim to protect human, animal and plant health can also impact on natural resource use. Other process regulations, like those governing organic farming, provide consumers with assurance of certain production practices and influence investment decisions. Environmental and health related regulations can boost innovation by building consumer and societal trust in the safety and sustainability of new products or processes, but unnecessary or dis-proportionate regulations can stifle innovation and technological developments.

Several government regulatory programmes on products and processes with a direct focus on agriculture have a significant link with innovation and sustainable productivity growth (Box 4.4). The programmes affect the nature of investment and innovation carried out by private firms, and can affect the mix of products offered by those firms. They include programmes aimed at agricultural pests and disease; environmental regulation, particularly as it is aimed at chemical use; the regulation of agricultural biotechnology; the regulation of livestock drugs; and the regulation of organic farming. Each of these programmes have a pronounced scientific bent, use risk-based analyses to support actions, and rely on significant public and private investments in research (Olmstead and Rhode, 2015; Olmstead and Rhode, 2008; Peck, 2013; Phillips, 2013; Fernandez-Cornejo et al., 2014).

Box 4.4. Economics of regulatory intervention for the environment, pests and diseases

Private efforts to control animal and crop pests and diseases, as well as environmental damage, are often limited by certain economic attributes of the activities: public goods, asymmetric information, and externalities. These attributes support public intervention, but also affect how public regulation is designed.

The term “public good” refers not to the provider of a product, but to two product attributes — non-rivalry and non-excludability. A product is non-rival if consumption of it by one individual does not reduce the amount available for another, and it is non-excludable if it is impossible to exclude any individuals from consuming it. Contagious disease control can be non-rivalrous: if one livestock owner benefits from a reduced incidence of disease that does not reduce the benefits available for others. Control may also be non-excludable: reducing the incidence of disease in a region can provide benefits to all producers, whether they pay for the control or not.

If products are non-excludable, consumers have no incentive to pay for them, but if no one pays there is no incentive to produce them. If products are non-rivalrous, then prices become a poor tool for rationing access, and there may be no good reason to ration access. Private markets may be ineffective in delivering public goods.

Public provision may be necessary in this case; however, the degree to which public good attributes hold can vary widely across products. Moreover, public provision alone does not solve the problem of providing a product and apportioning its use. As a result, effective public intervention will likely require different institutional designs for different circumstances.

Some animal and crop diseases may not be observable by buyers, even if sellers are aware — that is, there is asymmetric information in the markets. In that case, sellers therefore may obtain little direct benefit from disease control, because control cannot be observed by the buyer. The seller may have strong incentives to sell diseased animals in commercial channels before diseases become observable.

Similarly, pests migrate across farms. Individual efforts to manage pests may largely benefit other producers, such that a farmer gains little of the benefits from his or her own actions. In that case, an individual farmer again has little economic incentive to manage pests. Actions to control nutrient runoff to rivers from fields may largely benefit downstream users of the resource, while the farmer obtains little of the benefits from control.

Such externalities, in which an individual's actions generate uncompensated benefits or costs for outside parties, abound in disease, pest, and environmental management. If they are large enough, private decision-makers will not carry out control activities, because they do not capture enough of the benefits from their own expenditures.

Regulation of pests and disease

Pests and diseases can, if unmanaged, impose large direct costs on livestock and plant producers. They can reduce meat, dairy, and crop yields, foreclose marketing options, hamper product quality, and raise farmer costs. Some diseases are zoonotic, and therefore can have important effects on human health and health costs. Moreover, improvements in the control of animal and plant health may complement other agricultural innovations. Indeed, pest and disease risks can deter producer and processor investment in new products and production methods if diseased plants and animals do not show the same yield or quality improvements from new products or methods that healthy plants and animals do (Olmstead and Rhode, 2015). Since such investments often embody new innovations, such risks can reduce agricultural and food product innovation and productivity growth in the long run, creating costs for producers and consumers.

Primary responsibility for programmes aimed at protecting animal and plant resources from agricultural pests and disease lies with USDA's Animal and Plant Health Inspection Service (APHIS). The objectives of the APHIS are to i) keep foreign pests and disease out of the country; ii) provide an emergency response when foreign pests and disease do enter the country; iii) control or eradicate major domestic pests and disease; iv) prevent the interstate spread of disease and pests; and v) facilitate agricultural trade by attesting to the health status of outgoing animals.

The APHIS budget amounted to USD 1.14 billion in 2014, with USD 296 million devoted to animal health and USD 286 million devoted to plant health. The agency also allocated USD 58 million to plant pest and disease management, USD 99 million to wildlife services, and USD 232 million to agricultural quarantine inspection. The funds appropriated to agricultural quarantine inspection are supplemented with user fees collected at ports of entry. APHIS also works closely with USDA's Agricultural Research Service (ARS) on topics related to animal and plant health; the ARS budget included USD 189 million for crop protection in 2014, and USD 90 million for livestock protection. Resources devoted to APHIS animal and plant health programs have been cut in budgets enacted after the financial crisis. The 2014 allocations for animal and plant health were 15.2% and 17.3%, respectively, below their 2010 values.

The agency maintains a specific focus on foreign pests and disease because domestic plants and animals have more limited biological defences against them. Moreover, expanded agricultural trade and increased international travel and tourism increase the likelihood that foreign pests and disease will be introduced into the country (Peck, 2013).

APHIS acts to prevent non-native pest incursions through layers of safeguards including its port inspection activities of imported products, financed through a system of user fees, with fines imposed on violations. APHIS also directs several programmes aimed at identifying pests in other countries to prevent their export to the United States. Information from the programmes allows domestic APHIS staff to anticipate potential pest risks and adjust inspection procedures in response to changing risks. The agency also conducts offshore commodity pre-clearance and certification programmes to facilitate the export of low-risk products to the United States, and it works with trade partners to manage pests that might pose a significant threat to US agriculture.

The agency collaborates with State animal health agencies to combat domestic diseases that have significant economic impacts. The cooperating agencies implement surveillance at farms, slaughter facilities, and points of sale to identify diseased animals and herds. APHIS and cooperating agencies also utilise certification programmes to identify disease-free herds to provide sources of new stock. Control of disease may be realised through quarantines on herds and flocks; through movement restrictions; vaccinations, where possible; and through depopulation of diseased herds and flocks.

Effective control of pests and disease has necessitated the development of novel and innovative organisational arrangements. Specifically APHIS pursues a wide range of joint actions with other State and federal agencies, as well as other national governments. Moreover, the agency engages in public-private partnerships with private firms, academia, and with farms in support of surveillance activities and control pursuits (Olmstead and Rhode, 2015).

USDA's Bureau of Animal Industry, a forerunner agency to APHIS, the ARS, and the Food Safety Inspection Service (FSIS), led efforts to control and eradicate several animal diseases in the late 19th and 20th century. As part of that effort, the agency created fundamental new scientific breakthroughs that benefitted science and agriculture, initiated a range of new control technologies, and implemented organisational innovations to implement controls (Olmstead and Rhode, 2015).

Regulation of biotechnology

A Coordinated Framework for Regulation of Biotechnology, a science-based federal initiative, was introduced in 1986, and updated in 1992. The framework aimed to use existing statutory authority and agency expertise for a regulatory approach aimed at ensuring the safety of biotech products. A key regulatory principle is that biotechnology products should be regulated according to their characteristics and unique features, and not according to their production method — that is, regardless of whether they were created through the use of genetic engineering techniques. The three main federal agencies responsible for regulating the safe use of genetically engineered organisms are the US Environmental Protection Agency (EPA), the US Department of Health and Human Services' Food and Drug Administration (FDA), and USDA's APHIS.

The EPA regulates pesticides, including plants with plant-incorporated protectants (pesticides intended to be produced and used in a living plant), to ensure public safety under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Specifically, some Insect Resistant crops have been genetically engineered to carry a gene for a Bt (Bacillus thuringiensis) toxin; EPA requires the developer to verify that the toxin is safe for the environment and to conduct a food-safety analysis to ensure that the foreign protein is not allergenic.

As part of the registration process, the EPA requires technology developers and farmers to develop refuges of non-Bt crops near Bt crops; this has been the primary strategy for delaying the development of insect resistance, based on the idea that insects feeding on refuge plants are not selected for resistance. Farmers purchasing Bt seed are surveyed by a third party to measure compliance with the regulations, and those who are out of compliance risk losing access to the technology. Nonetheless, compliance was far from complete, in the range of 70-80%, and there was concern that rising maize prices would lead to declines in compliance (Goldberger, Merrill, and Hurley, 2005). In response to those concerns, seed companies have moved to mixing Bt and non-Bt seeds in seed bags (a programme marketed as "refuge in a bag"), instead of relying on farmers to plant non-Bt refuges adjacent to or in parts of Bt fields.

The FDA is responsible for regulating the safety of GE crops that are eaten by humans or animals. According to a policy established in 1992, FDA considers most crops produced from GE seeds as "substantially equivalent" to crops produced from seeds without GE traits. In such cases, GE crops are designated as "Generally Recognised as Safe" under the Federal Food, Drug, and Cosmetic Act (FFDCA) and do not require pre-market safety approval. If, however, the insertion of a transgene into a food crop results in the expression of foreign proteins that differ significantly in structure, function, or quality from natural plant proteins and are potentially harmful to human health, FDA reserves the authority to apply more stringent provisions of FFDCA requiring the mandatory pre-market approval of food additives, whether or not they are the products of biotechnology.

APHIS, through its Biotechnology Regulatory Services (BRS) programme, regulates the importation, interstate movement, and field testing of GE plants and organisms that are or might be plant pests — defined as organisms that cause disease, injury, or damage to plants or plant products, including viruses, bacteria, fungi, and parasitic plants. A regulated plant cannot be introduced into the environment, even for field testing, without APHIS authorisation. The agency enforces guidelines for field testing and for data to be collected and reported during testing. A sponsor may seek "non-regulated status" from APHIS after field testing as a step toward commercial release. APHIS conducts environmental and pest risk assessments before deciding whether to approve non-regulated status.

Gaps remain in the existing regulatory system regarding accidental contamination from GE crops (Carter and Gruère, 2012). Aside from issues concerning the enforcement of refuges for Bt crops noted above, GE crop varieties in regulated field trials, which were not approved for commercial release, were found to be commingled in commercial shipments in several high-profile cases, leading to the closure of important export markets. In several other cases, Federal courts have stopped the distribution of new GE seed varieties, on the grounds that USDA had not properly considered coexistence issues — how to prevent the commingling of GE varieties with organic and non-GE crop varieties, which would impose economic damages on the organic and non-GE growers. While the US Supreme Court later vacated the lower court rulings, the issue remains contentious, and the current regulatory framework for GE crops does not explicitly account for economic damages arising from commingling.

The Obama Administration embarked on a review of the Coordinated Framework in 2015. The Administration argues that advances in biotechnology have altered the biotechnology landscape since 1992, enabling the development of products not foreseen at that time. Moreover, it argues that the current regulatory system, while protecting health and the environment, encompasses a complex set of rules administered by three different agencies, which imposes unnecessary costs and burdens in some cases, as well as a lack of predictability of timeframes for review (Executive Office of the President, 2015). The review is expected to result in the development of an updated Coordinated Framework to clarify the roles and responsibilities of agencies that regulate biotechnology products by the summer of 2016.

Regulation of animal drugs

Antibiotic drugs are used for treatment of animal diseases, and they are provided in feed or water to control and prevent transmission of disease among herds and flocks. Antibiotics have also been used for "production purposes", because they have been found to improve the efficiency with which feed is converted to weight gain and reduce the time needed for animals to reach market weights. By the end of 2016, new federal rules will remove approval for the use of medically important drugs for production purposes.

While the primary agricultural use of antibiotics lies in livestock production, antibiotics are also used in aquaculture and in some specialty crops, and appear to be heavily used in the care of companion animals (Hollis and Ahmed, 2014).

When used for disease treatment, control, and prevention, antibiotic drugs improve productivity growth in livestock agriculture by reducing animal mortality and morbidity; drugs administered for production uses also contribute to productivity growth by reducing the amount of feed and housing required for any given amount of production. Antibiotic drugs are used widely in the United States — although not universally — for disease treatment and prevention and for production purposes in livestock industries, and particularly in fed cattle, swine, and poultry production. The impact of antibiotic provision on feed conversion (a production purpose) appears to have declined over the years. The decline may reflect growing pathogen resistance but may also reflect changes in animal genetics, feeding formulations, housing, and production practices (Sneeringer et al., 2015).

Antibiotics kill a wide range of pathogenic bacteria that harm humans and animals and have provided enormous health benefits in the last 80 years. However, they are losing their effectiveness to treat human illnesses because bacteria are evolving resistance to them. Use of antimicrobial drugs creates selective evolutionary pressure that enables antimicrobial resistant bacteria to increase in numbers more rapidly than antimicrobial susceptible bacteria and thus increases the opportunity for individuals to become infected by resistant bacteria. Resistance to specific antibiotic drugs can spread among bacteria, jump from one type of bacteria to another, and move across regions. Growing resistance follows in part from widespread use of antibiotics in humans and animals.

Individual decisions to use antibiotics, whether prescribed by a doctor to treat a cold or sore throat that will get better without drugs, or administered by a farmer to promote more rapid weight gain, are generally carried out without regard to the costs that may be imposed on others through the impact on antimicrobial resistance. On the other hand, a decision to forego an antibiotic carries some risks for the person going without, while the benefits, in terms of a reduced spread of resistance, go to others. In short, antibiotic use creates uncompensated costs or benefits for others, which have little influence on decision-makers' calculations. This is a classic instance of externalities, under which private markets are likely to induce overuse of antibiotic drugs.

The Food and Drug Administration (FDA) of the Department of Health and Human Services has responsibility for approval of drugs used in human or animal medicine. The FDA's process focuses on whether the drug is safe and effective for its indicated uses.

The United States has long had regulations focused on testing for and controlling antibiotic residues in animal products. As part of its approval process, the FDA establishes minimum withdrawal periods between the last use of a drug and slaughter, which allows time for the drug to fall below the tolerance level deemed appropriate for human consumption. If the withdrawal time is followed, food products made from the treated animal are considered safe for people to eat. USDA's Food Safety and Inspection Service's (FSIS) monitors animal products at slaughter facilities and US ports of entry to test antibiotic residue levels (and other substances) in meat samples. Carcasses found with residue violations may be partly or entirely condemned.

The FDA also has primary responsibility for monitoring antibiotic residues in milk. If cows have been treated with antibiotics, they must undergo a withdrawal period before their milk can be considered safe for human use. Monitoring is carried out by state regulatory agencies, acting under contracts with the FDA. Milk is collected in specialised tankers at dairy operations, either daily or every other day. Samples are taken from each tanker arriving at a processing plant, and if a sample tests positive for antibiotic residues, the entire tank must be dumped, entailing a financial cost to the producer.

The FDA is also responsible for ensuring that antimicrobial drugs are used judiciously, so as to slow the development of resistance. In pursuit of that goal, the agency has introduced a guidance supporting two important changes, beginning in 2017, in the marketing of medically important antimicrobial drugs used in livestock production (US Food and Drug Administration 2013). The agency classifies specific drugs as medically important based on their microbiological effects on bacteria of human health concern.

The agency will withdraw approval of the use of medically important drugs for growth promotion or production purposes; they will only be approved for use in livestock production for disease treatment or prevention. The FDA also proposes to move all use of medically important drugs to veterinary oversight. Previously, many antimicrobial animal drugs were given over-the-counter (OTC) marketing status, which is generally provided for products for which adequate directions for use can be written for lay persons. Based on the evidence regarding antimicrobial resistance, FDA believes that judicious use decisions require the scientific training of a licensed veterinarian. Under the new guidance, medically important antibiotic drugs will have to be distributed under Rx prescription (for drugs delivered in water) or Veterinary Feed Directive (VFD, for products delivered in feed).

There is considerable consumer and retailer interest in the US in meat products that have been raised without antibiotics, and their actions can affect antibiotic drug use irrespective of changes in federal regulation and guidances. However, such products must be advertised and labelled to influence consumer behaviour. Many consumers appear to be willing to pay price premiums for products labelled as "raised without antibiotics" (implying no antibiotics provided for production purposes) and for products labelled as "never administered antibiotics" (implying no antibiotics administered for any purpose). However, because consumers have no way of directly ascertaining the truthfulness of claims regarding antimicrobial drug use (or other on-farm production practices), firms could have strong incentives to issue misleading or inaccurate claims. In that case, markets are unlikely to effectively transmit consumer preferences to producers.

USDA/FSIS has responsibility for approving label claims made regarding meat products, including claims regarding antibiotic usage, while USDA's Agricultural Marketing Service (AMS) provides process verification services for animals raised according to certain specified production practices, including processes that forego antibiotics. Each agency faces the challenge of defining the substances that are to be classified as antibiotics, and defining precisely what specific label claims mean, in ways that are informative and useful for consumers.

Regulation of organic farming

The federal regulation on organic agriculture imposes standards for organic farming under the framework of the Organic Food Production Act, and of the USDA organic regulations. Like other OECD countries, overall, organic farming in the United States is based on the following general principles and rules: preserve natural resources and biodiversity; support animal health and welfare; provide access to the outdoors so that animals can exercise their natural behaviour; only use approved materials; do not use genetically modified ingredients; and separate organic food from non-organic food.

To ensure that these rules are being followed, and in the interest of good consumer information, the USDA has developed a set of standards for agricultural practices that, if followed, make producers and processors eligible for organic farming labelling. The certification of organic farming labelling is given by the USDA, and requirements are controlled by agents who should receive accreditation for doing so. One important dimension is the potential for expanding market shares through trade.

Beyond this regulatory role, the United States provides support to Organic Agriculture, through a set of funding, grants, specific organic insurance programme, and microloans. To facilitate the pursuit of these development efforts, a new Guidance on Organic Agriculture, Marketing and Industry, issued in 2013, "directs all USDA agencies to support organic agriculture and markets."

Trade and investment policy

Trade can facilitate the flow of goods, capital, technology, knowledge and people needed to innovate. Openness to trade and capital flows is conducive to innovation as it provides a larger market for innovators, reinforces competition, increases access to new technologies, ideas and processes, including from foreign direct investment (FDI) and related technological spill-overs, and facilitates cross-country collaboration. Trade and investment openness can influence innovation throughout the food supply chain, from input suppliers to food service and retail firms. Input and output markets that operate effectively can foster productivity growth. Trade and investment openness can also facilitate the development of market mechanisms to foster more environmentally sustainable production.

The United States has historically been open to trade. Tariff barriers have been consistently low by world standards, as shown in Chapter 6.

The United States participates in several major regional trade agreements, the most notable of which is the North American Free Trade Agreement (NAFTA), an agreement with Canada and Mexico. These two countries receive the greatest share of US exports, and are two of the three largest sources for US imports (Global Trade Atlas, 2015). The United States has also concluded a free trade agreement with the Central American countries, the Central American Free Trade Agreement (CAFTA). In addition, the United States is in the process of finalising an agreement with fellow Pacific Rim nations, the Trans-Pacific Partnership Agreement (TPP), and is currently negotiating an agreement with the European Union, the Transatlantic Trade and Investment Partnership (TTIP). All these agreements contain provisions affecting agricultural trade.

The United States has also negotiated a number of bilateral free trade agreements with individual countries, including Australia, Bahrain, Chile, Colombia, Israel, Jordan Morocco, Oman, Panama, Peru, Singapore, and Korea (US State Department, 2015).

The barriers to trade and investment in the United States are moderate among OECD countries (Figure 4.5). At 0.60 on a 0 (least) to 6 (most restrictive) scale, the US score on the OECD's Barriers to Trade and Investment Index in 2008 was equal to the OECD average, lower than in Canada or Mexico, but higher than the average of EU28 member state (0.45). In most countries, restrictions have continued to decrease between 2008 and 2013, with the OECD score now averaging 0.52. More recent data for the United States is not available. The index includes four components: tariffs; trade facilitation, which measures the availability of US trade regulations to exporters in other countries, as well as whether countries use international standards for products and recognise equivalent standards of other countries; barriers to Foreign Direct Investment (FDI); and differential treatment of foreign suppliers. US scores that are significantly above zero (i.e. potential barriers to trade and investment) include restrictions on mergers and acquisitions in certain sectors, and restrictions on foreign providers of legal services, which are reflected in the relatively high score for differential treatment of foreign suppliers (Figure 4.5B).

Barriers to trade facilitation are low and a number of measures have or are being put in place to facilitate trade. They include the establishment of a single-window application across all agencies, through which traders can submit electronic data for importation and exportation; and the creation in 2014 of a Border Interagency Executive Council (BIEC), which is in charge of developing common risk management principles and methods; developing policies and processes to improve and accelerate electronic data treatment, in consultation with stakeholders; encouraging other countries to develop similar single window systems to facilitate sharing of data, and assessing opportunities to facilitate electronic payments of duties, fees and taxes (WTO, 2014).

The United States has some barriers to FDI, as illustrated by the OECD Restrictiveness Index for FDI being consistently 0.089 during the period 1997-2014 (Figure 4.8). During that time the OECD average fell from 0.127 to 0.068, but the index remains higher than in the United States in major OECD regions such as Australia, Canada or the EU28 average, as well as in BRIICS countries. An examination of the underlying data indicates that the largest US barriers to FDI fall under the heading of restriction on foreign equity, and less on the other components of the index, including screening/approval of foreign purchases, restrictions on foreign personnel, and other restrictions (Kalinova et al., 2010).

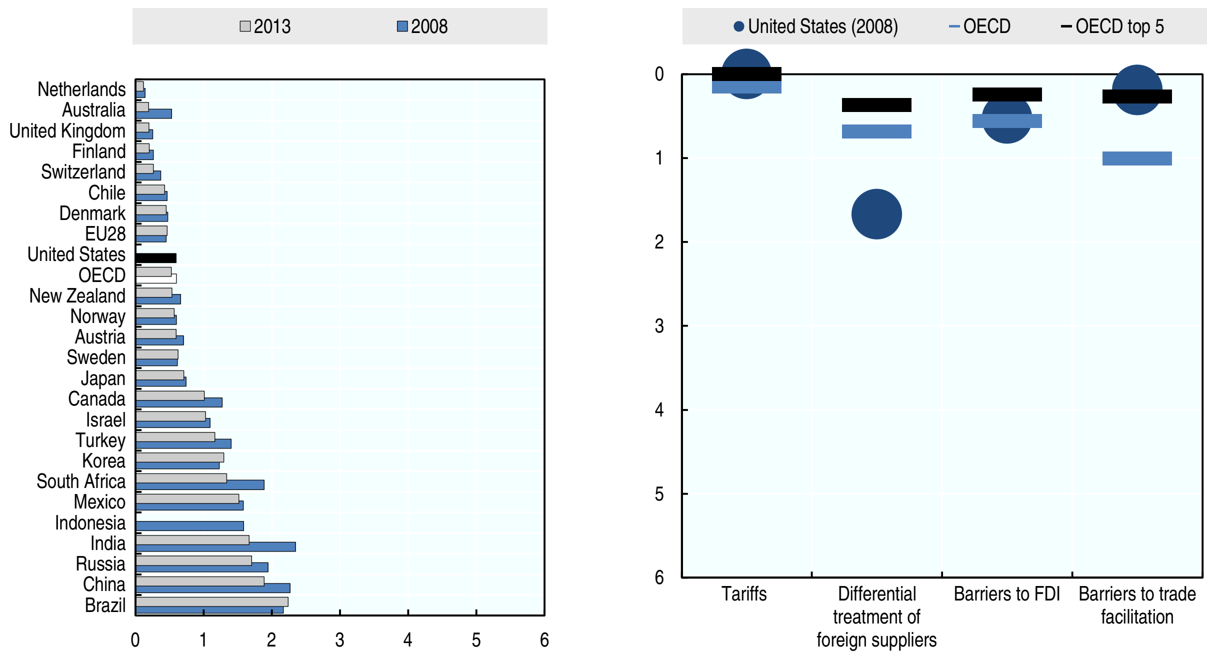
For the agriculture and food categories, the US Restrictiveness Index has been 0 consistently in both the food and the agriculture subsectors since 1997, and, as such, has been well below the OECD average (Figure 4.6). The only agriculture-related provisions regarding foreign investment are that foreign ownership of agricultural land must be reported to the Secretary of Agriculture and that US citizenship is required for a permit to allow grazing on public land (WTO, 2014, Table 2.4).

Figure 4.5. Index of regulatory restrictions to trade and investment, 2008 and 2013

Scale from 0 (least) to 6 (most) restrictive

A. Index of regulatory restrictions to trade, by country, 2008 and 2013

B. US index of regulatory restrictions to trade, selected component, 2013



Indices for EU28 and OECD are the simple average of member-country indices. Barriers to trade facilitation refer to the extent to which the country uses internationally harmonised standards and certification procedures, and Mutual Recognition Agreements (MRAs) with at least one other country. OECD top 5 refers to the average of the scores for the top five performers among OECD countries (Netherlands, Luxembourg, Ireland, United Kingdom and Finland).

Source: OECD (2014) Product Market Regulation Database. www.oecd.org/economy/pmr.

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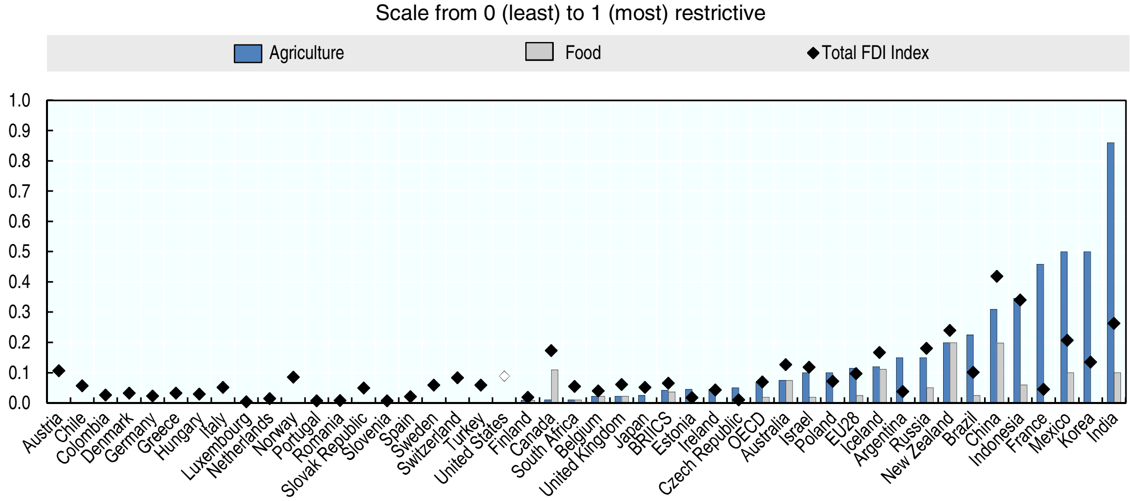
Figure 4.6. OECD FDI Regulatory Restrictiveness index, by sector, 2014

Scale from 0 (least) to 1 (most) restrictive



Indices for OECD are the simple average of member-country indices. Four types of measures are covered by the FDI Restrictiveness Index: 1) foreign equity restrictions, 2) screening and prior approval requirements, 3) rules for key personnel, and 4) other restrictions on the operation of foreign enterprises.

Source: OECD (2015b), Investment Statistics, FDI Regulatory Restrictiveness Index. www.oecd.org/investment/fdiindex.htm.

StatLink http://dx.doi.org/10.1787/888933408492

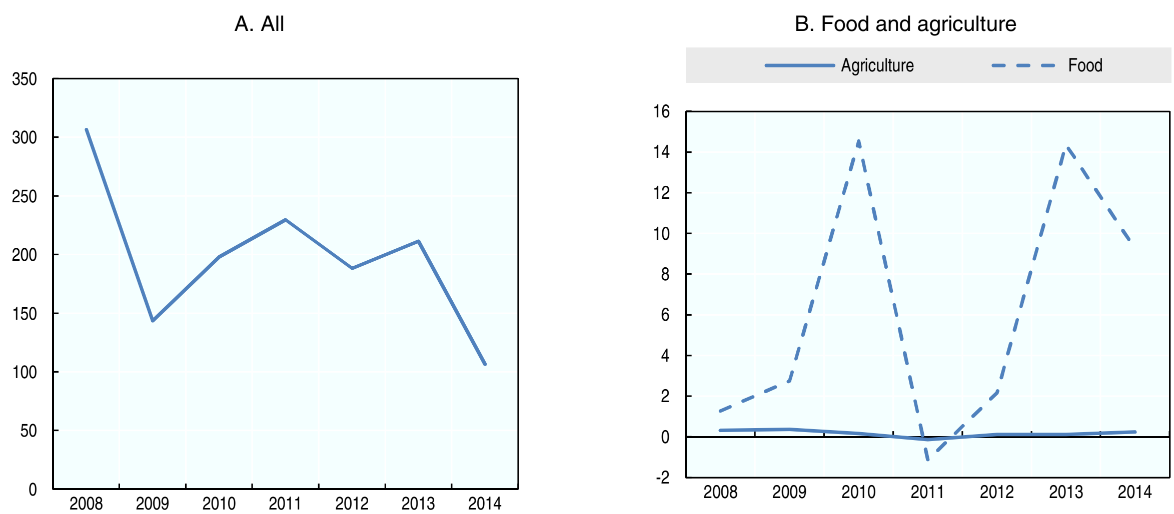
Annual inflows of FDI have been falling in the United States (Figure 4.7A). Overall inflows into the country follow the business cycle: they declined in 2008-09, and again from 2011 to 2014 (Jackson, 2013; US Department of Commerce, 2015). This follows a period in the late 1990s early 2000s in which it was particularly high (Jackson, 2013). The United States has traditionally served as a safe haven for investors, and therefore the cumulative sum of FDI into the country has been rising, but at a slower rate, as inflows fall (Figure 4.8A). In 2014 FDI stock as a percentage of GDP was close to the OECD average (Figure 4.9).

FDI in agriculture is low compared to total FDI (Figure 4.7B). Inflows of FDI in agriculture, forestry and fishing have averaged about 0.1% of total FDI inflows, and 0.2% of cumulative FDI, despite low barriers to investment, a lower share than would be predicted by agriculture's share of GDP.

Foreign direct investment in the food industry (food, beverage, and tobacco processing) has been large. The food industry's share in annual FDI inflows (8.8% on average from 2011 to 2014) have been considerably greater than the share of the industry in GDP (1.4% in 2014), and the industry's share of cumulative FDI (an average of 3.4% from 2008 to 2014) also exceeds its share in GDP (Figure 4.8B. Annual flows vary sharply from year to year; corporate mergers are an important element in food FDI, and these can be very large and intermittent events (Kwoka, 2015; Connor and Schick, 1997; US Federal Trade Commission, 2015).

Figure 4.7. FDI inflows into the United States, 2008-14

Billion USD

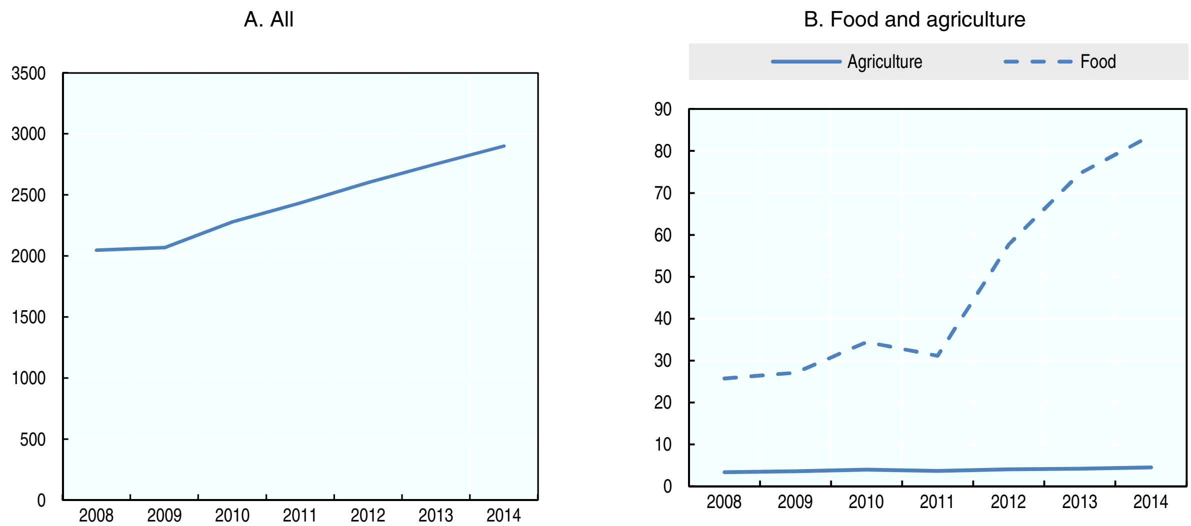


Source: US Department of Commerce (2015), *Bureau of Economic Analysis,* www.bea.gov/international/index.htm#iip.

StatLink http://dx.doi.org/10.1787/888933408503

Figure 4.8. Cumulative FDI into the United States, 2008-14

Billion USD

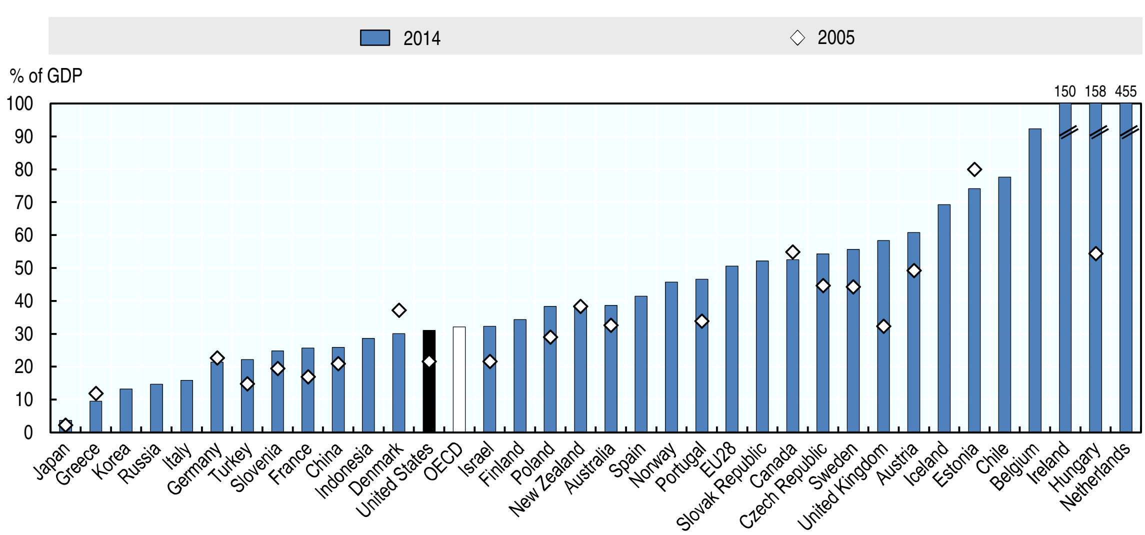


Source: US Department of Commerce (2015), *Bureau of Economic Analysis*, www.bea.gov/international/index.htm#iip.

StatLink http://dx.doi.org/10.1787/888933408516

Figure 4.9. Total FDI inward stocks by country, 2005 and 2004

As a percentage of GDP, 2005 and 2014 or latest available year



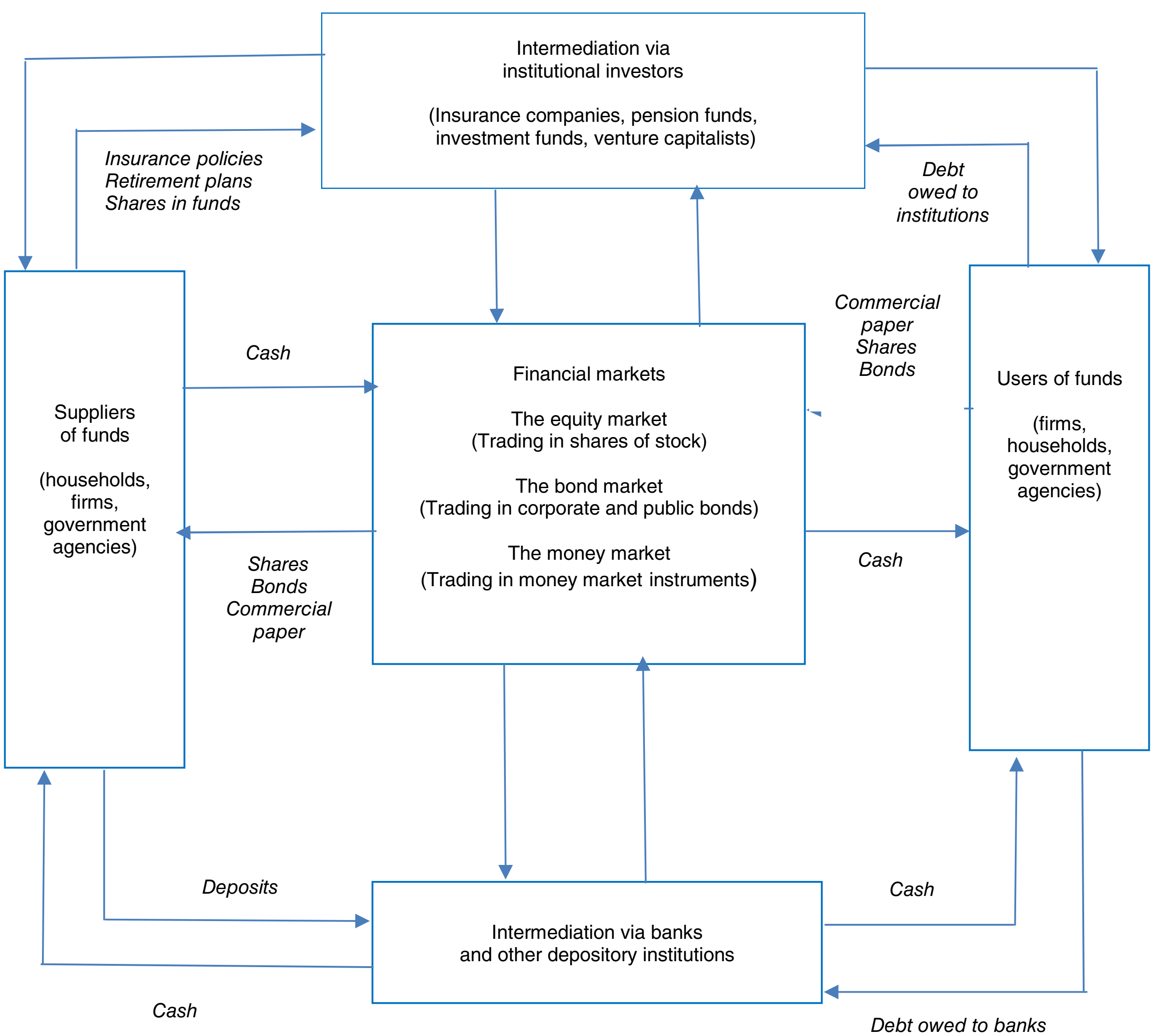
Source: OECD (2015d), *International Direct Investment Statistics, Benchmark definition*, http://stats.oecd.org/BrandedView.aspx?oecd_bv_id=idi-data-en&doi=data-00746-en.

StatLink http://dx.doi.org/10.1787/888933408521

Finance policy

Efficient financial markets are one key to enable balanced development of any economy and society. Access to financial services can be limited or unequal across regions and firms when financial markets fail or when risks are too high. Policies that improve the functioning of financial markets can facilitate productivity-enhancing investments in agriculture, and enable the most efficient firms to expand. Policies may also facilitate access to funding for sustainability enhancing investments. Low cost loans and venture capital can also be an important source of funding for innovative firms with high growth potential. In the United States, the ready availability of agricultural credit has facilitated considerable gains in agricultural productivity, the mechanisation and modernisation of farming operations, more orderly marketing of farm commodities, and liquidity management (Barry and Robison, 2002). The USDA has also sought to ensure the availability of credit for young, beginning, and disadvantaged farmers, who may otherwise not have had access. However, studies have consistently shown that attempts to convey subsidies through financial markets, as opposed to ensuring access, have been largely ineffective (Barry and Robison, 2002).

Figure 4.10. The US financial system

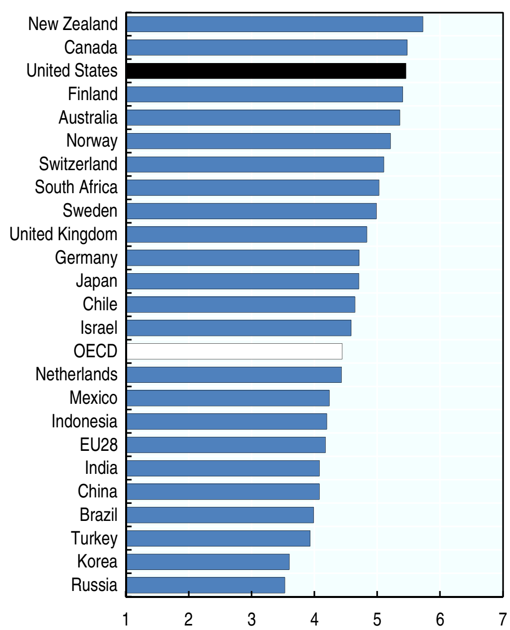


The United States has a very large and deep financial sector that maintains close links to global financial markets. Financial intermediaries — such as banks, pension funds, insurance companies, and investment funds — aggregate the savings provided to them by households, firms, and government agencies (see Figure 4.10 above, a simplified depiction of the US financial system). They may also raise funds in financial markets, rather than access funding directly from suppliers of funds, and some financial intermediaries acquire all of their funding in this way.

Figure 4.11. Global Competitiveness Index: Financial market development, 2015-16

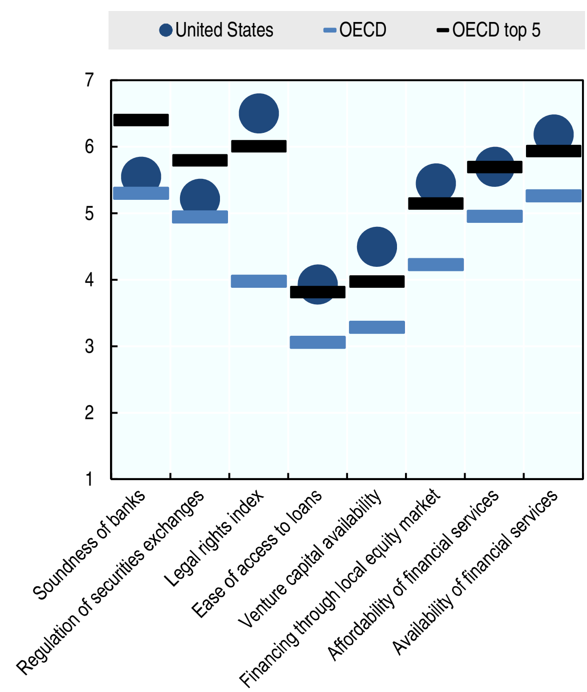
Scale 1 to 7 (best)

A. Total index of financial market development, by country



Indices for EU28 and OECD are the simple average of member-country indices.

B. US index of financial market developments, by component



OECD top 5 refers to the average of the scores for the top 5 performers among OECD countries (New Zealand, Canada, United States, Finland and Australia).

The Legal rights index is scored on a scale from 1 to 10 based on calculations by the WEF from the World Bank–International Finance Corporation's Doing Business 2015.

Source: World Economic Forum (2015), *The Global Competitiveness Report 2015-2016,* www.weforum.org/reports/global-competitiveness-report-2015.

StatLink http://dx.doi.org/10.1787/888933408530

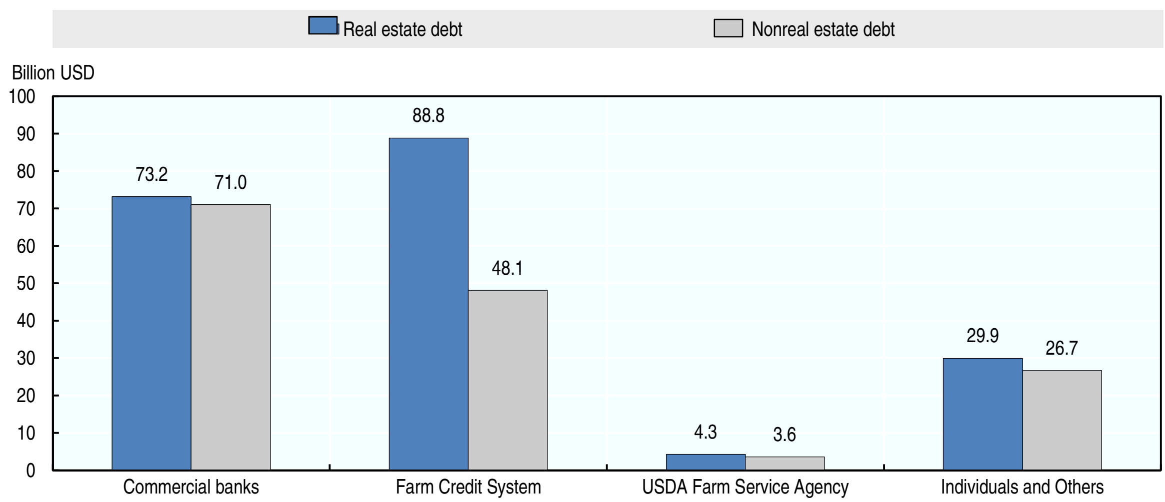
Financial intermediaries may lend directly to users of funds, but they may also act through financial markets to lend indirectly through the purchase of stocks, bonds, and other financial market instruments. Major financial institutions often provide sources of funds to smaller financial institutions and nonfinancial lenders to business, as well as to investment banks.

According to WEF competitiveness indicators, the United States ranks among the OECD top five in terms of financial market development (Figure 4.11). The components of the US financial market indicator outline its strength in terms of the availability and affordability of financial services and access to financing through local equity markets. The United States is also top in the OECD (together with

Finland) in terms of availability of venture capital, which has been crucial for the financing of innovative start-ups in information technology and biotechnology.

Two types of financial intermediaries — commercial banks and the Farm Credit System (FCS) — accounted for 81% of all lending to the farm sector in 2014, when total US farm sector debt amounted to USD 345.7 billion (Figure 4.12). Commercial banks, which raise funds from depositors and from equity and debt providers in financial markets, split their lending almost evenly split between real estate and non-real estate lending. Nearly two-thirds of FCS farm loan volume was secured by real estate.

Figure 4.12. Farm sector debt, by type of lender, 2014



Source: USDA (2015), *Economic Research Service, Farm Income and Wealth Accounts*, www.ers.usda.gov/data-products/farm-income-and-wealth-statistics/balance-sheet.aspx.

StatLink http://dx.doi.org/10.1787/888933408540

The FCS, created by Congress in 1916 to provide a source of reliable credit for agriculture, is a network of borrower-owned cooperative financial institutions and service organisations. FCS institutions provide credit and financially related services to farmers, ranchers, and aquaculture producers, and to their cooperatives. The FCS also makes credit available for certain farm-related businesses, rural housing, rural utilities, and foreign and domestic activities in connection with international agricultural trade. Loans to production agriculture represented 69% of total loans outstanding in 2014.

The FCS raises funds for its business activities by selling securities in national and international money markets. Its system-wide debt funding is subject to approval by an independent regulatory agency (the Farm Credit Administration), and its securities are not guaranteed by the Federal Government.

Four Farm Credit banks raise funds and provide credit to 74 Agricultural Credit Association (ACA) parent organisations and two stand-alone Federal Land Credit Associations (FCLAs). Each ACA contains two subsidiaries, a Production Credit Association which can make only short- and intermediate-term loans, and an FLCA, which can only make long-term real estate loans. FLCAs are exempt from State and federal income taxes.

Life insurance companies are also significant providers of finance to agriculture, and the largest single entity under "Individuals and others" (Figure 4.12). Life insurance companies held about USD 12 billion in real estate debt in 2014, and an undisclosed amount of non-real estate debt. Loans from life insurance companies are concentrated among relatively large farms, especially livestock producers and fruit and vegetable operations.

Federal policy also seeks to make credit more easily available to new and beginning farmers. Through the Farm Credit Act, Congress requires FCS banks and associations to have programmes to provide financially sound credit to young, beginning, and small (YBS) farmers. System institutions offer interest rate concessions, certain exceptions to underwriting standards, and concessionary loan fees to YBS farmers and ranchers to meet that mandate.

Acting through the Farm Service Agency (FSA), USDA directly provides ownership and operating loans to family farmers, emergency loans for losses from natural disasters, and conservation loans to finance completion of a conservation practices in an approved conservation plan. Loan recipients must be actively engaged in the farming operation, and direct loans cannot exceed certain maximums. FSA accounted for about 2% of farm sector debt in 2014 (Figure 4.12).

FSA also provides guarantees for qualifying loans made by other financial institutions, such as commercial banks or FCS institutions. Guarantees cover up to 95% of the principal and interest outstanding in the event of default. By 2013, the volume of guaranteed loans was 60% greater than that of direct loans with the guaranteed loan programme, with the goal of reducing risk and interest rates through increased liquidity.

FSA direct loans and guarantees are directed to farmers who would not qualify for loans from commercial lenders, typically because they have little wealth and limited farming and credit experience. Fifty percent of the volume of direct and guaranteed loans is held by beginning farmers and 24% is held by women and minority farmers. FSA losses on direct loans are quite low — loan losses have amounted to less than 1% of the outstanding principal balance in 2014 and 2015, and repayment delinquency rates have consistently been between five and six percent of outstanding balances. Losses on guaranteed loans have been lower, with delinquency rates between 1 and 2% of outstanding balances.

Tax policy

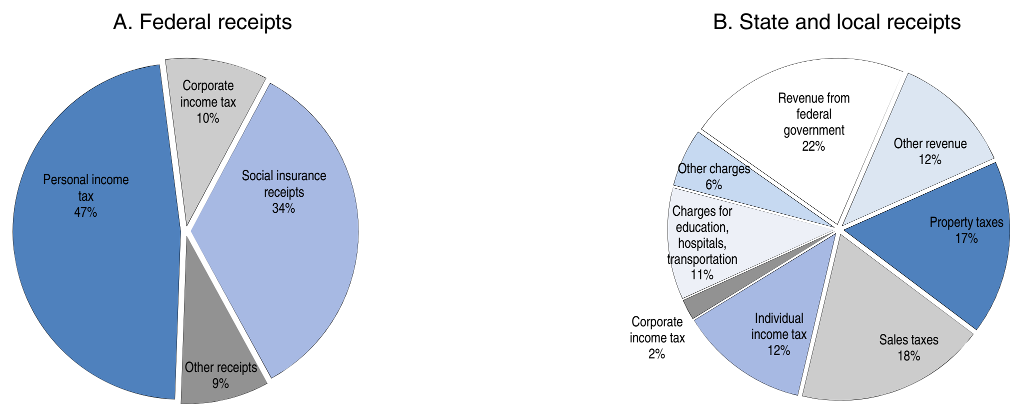
Tax policy affects innovation, productivity and sustainability in many ways: it affects the decision of firms and households to save or invest in physical and human capital, and thus the adoption of innovation; it raises government revenues, which can then finance public services, including those enabling innovation such as education and skills, R&D, and strategic infrastructure; it can also be used to provide direct incentives, for example preferential tax treatment to investments in private R&D or to young innovative companies. In addition to its economy-wide impacts, tax policy influences the conduct, structure and behaviour of farms, input suppliers and food companies. Taxes on income, property and land and capital transfer, including land, may affect structural change, while differential tax rates on specific activities (polluting or environmental friendly), resources, or input use may affect sustainability.

The Federal Government raises nearly half of its revenue from personal income taxes while relying on social insurance payroll taxes for just over one-third, and corporate income taxes for about one tenth (Figure 4.13a). State and local governments rely on a wider range of sources of funds (Figure 4.13b). About 22% of state and local funds come through transfers from the federal government, while property, sales, individual income and corporate income taxes and sales taxes and direct charges for activities together account for 50%. Direct charges — for education, hospitals, transportation, and other functions—contributes about one-sixth of state and local receipts.

Farms and agribusinesses — including those involved in food processing, wholesaling, retailing, and farm input — are subject to the wide range of different taxes and charges at federal, state, and local levels. These taxes have a significant impact on the management and investment decisions of farmers and agribusinesses with regard to investment in both human and physical capital.

The federal income tax has the greatest potential impact on investment, management, and production decisions in the agricultural sector. Farmers benefit from both general tax provisions available to all taxpayers and from provisions specifically targeted to farmers. In general, income from farming is taxed more favourably than income from many other businesses. Some of the specific provisions that are responsible for this treatment include the current deductibility of certain capital costs, capital gains treatment of proceeds from the sale of farm assets, cash accounting, and farm income averaging. These and other provisions reduce the farm income tax base, allow some farm income to be taxed at reduced rates, and contributes to smoothing annual income variations.

Figure 4.13. Federal, state and local government receipts, by source, 2013



Source: Economic Report of the President (2016) www.whitehouse.gov/administration/eop/cea/economic-report-of-the-President/2015.

Source: US Census Bureau (2015). www.census.gov/.

- **Capital Gains Treatment for Assets Used in Farming**. Although assets used in a trade or business (section 1231 property) are not capital assets, gains from the sale of such assets are treated as capital gains, and losses are treated as an offset to ordinary income. Among the farm assets eligible for such treatment are farmland and livestock held for draft, dairy, breeding, or sporting purposes.

- **Current Deduction for Development Costs.** Another feature of the federal income tax that applies specifically to farmers is the ability to deduct the cost of developing certain farm assets in the tax year when the costs are incurred or paid. Examples of pre-productive development costs include raising dairy, draft, breeding, or sporting livestock to their age for mature use, caring for orchards and vineyards before they are ready to produce crops, and clearing land and building long-term soil fertility by applying lime, fertiliser, and other materials.

- **Cash Accounting**. While businesses are generally required to use the accrual method of accounting for tax purposes, most farm sole proprietors are allowed to use the cash method of accounting. A large number of farm partnerships and small business corporations also are allowed to use the cash method. Only corporations (other than a family corporation) that had gross receipts of more than USD 1 million for any tax year beginning after 1975 or a family corporation that has gross receipts of more than USD 25 million for any tax year after 1985 are required to use the accrual method of accounting.

- **Current Deduction for Soil and Water Conservation Expenditures.** Since 1954, farmers have been allowed to claim immediate federal income tax deductions for certain types of expenditures on soil and water conservation or for the prevention of erosion of land used in farming. Examples of expenses have included levelling, grading, terracing, custom furrowing, planting windbreaks, and constructing, controlling, and protecting diversion channels, drainage ditches, irrigation ditches, earthen dams, watercourses, outlets, and ponds.

- **Income Averaging**. Under the current law, a farmer can elect to shift a specified amount of farm income, including gain on the sale of farm assets except land, to the preceding three years and pay tax at the rate applicable in each year. The current income shifted back is spread equally among the three years. If the marginal tax rate was lower during one or more of the preceding years, a farmer may pay less tax than without income averaging. This helps to reduce the potential higher taxes that might otherwise occur as a result the combination of variable farm income and a progressive tax rate structure.

In addition to targeted provisions, farmers and agribusinesses benefit from various general provisions including the tax treatment of capital investments. Over the last decade, the amount that could be immediately expensed has increased substantially to USD 500 000 in 2014. Recent legislation (The Protecting Americans from Tax Hike Act of 2015) made the USD 500 000 expensing provision permanent.

In addition to this expensing amount, an additional first year depreciation deduction of 50% has been provided. The 2015 legislation noted above extended the additional first-year depreciation deduction through 2019, but limited it to 40% in 2018 and 30% in 2019. Allowing a large share of investment to be recovered at an accelerated rate reduces the tax rate and encourages additional capital investment.

At the state and local level, property taxes are of the greatest significance. All states have at least one programme designed to reduce the amount that farmers are required to pay in state and local property taxes. The most important type of programme allows farmland to be valued at its farm use value rather than its fair market value. This can provide significant property tax relief, lowering farm operating expenses and reducing the potential that financial pressures could force some farmers to sell their land for development purposes.

Sole proprietorships, partnerships, and subchapter S corporations are all taxed at the individual level. The most common form of farm organisation is the sole proprietorship which, according to the 2012 *Census of Agriculture*, comprises 87% of all farms. Partnerships comprise about 6.5% of farms while corporations account for about 5%. Income from farm partnerships and subchapter S (small business) corporations is also passed through to the individual partners or shareholders for taxation at the individual shareholder or partner level. While the Census does not separate subchapter S corporations from other corporations, family-held corporations account for about 90% of all corporations. Most of these corporations are subchapter S corporations. Therefore, about 97% of all farms are taxed under the individual income tax rather than the corporate income tax.

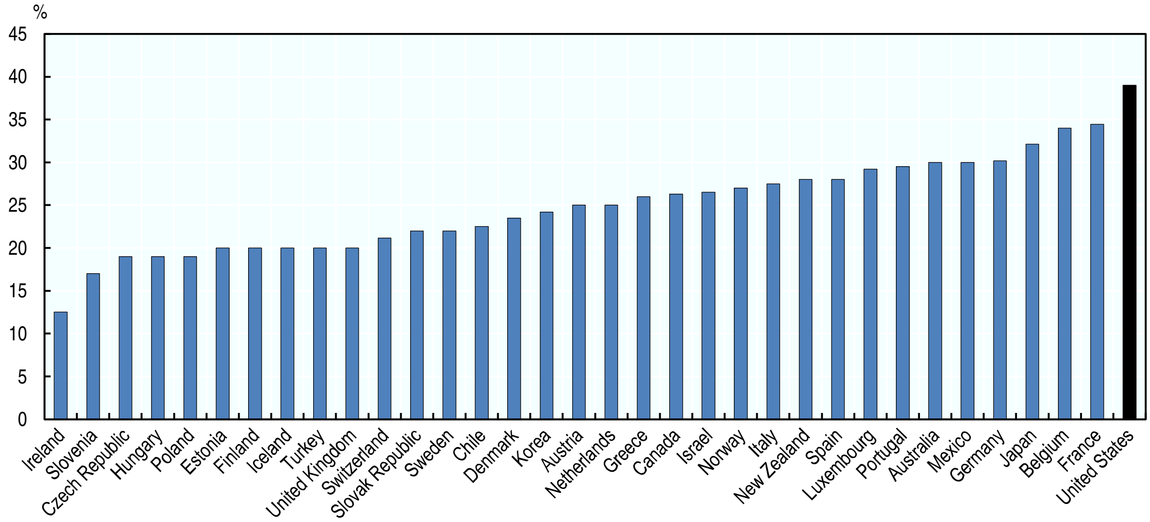
Most agribusinesses are large corporations and taxed under the corporate income tax structure. The applicable federal and state income tax rate structures for both individual and corporate taxes are presented in Table 4.1.

Table 4.1. US income tax rates by organisation structure

Type of organisation Federal State			Combined marginal rates
Individual	10.0-39.3%	0.0-13.3%	10.0-52.6%
Corporate (regular)	10.0-35.0%	0.0-9.99%	10.0-44.9%

Source: Internal Revenue Code.

Figure 4.14. Combined corporate income tax rate, 2015[1]



1. Basic combined central and sub-central (statutory) corporate income tax rate given by the adjusted central government rate plus the sub-central rate.

Source: OECD (2015c), OECD Tax Database, www.oecd.org/tax/tax-policy/tax-database.htm.

StatLink http://dx.doi.org/10.1787/888933408552

While the United States has the highest corporate income tax rates (Figure 4.14), a variety of special provisions narrow the base of corporate income that is subject to tax. Consequently, corporate taxes provided only 6.7% of total government receipts in 2013, and amounted to 2.1% in the US GDP, compared to an OECD average of 2.9%.

The weight of taxation on labour costs is lower than the OECD average. The tax burden (Income tax plus employee and employer contributions less cash benefits) as a % of labour costs for single persons without children at 100% of average earnings was about 32% in 2015, which is below the OECD average of 36% (OECD, 2016b, Table 6.2a). While the share of income tax is higher than average, employee and employer social security contributions are much lower. As a result, social contributions do not burden the cost of hired labour, including farm labour with low wages (Chapter 5).

An OECD examination of the efficiency of the US tax system in supporting growth notes that numerous exemptions to corporate and personal income tax distort economic activity and are often regressive (OECD, 2015b). A number of recommendations are made to "cut the statutory marginal corporate income tax rate and broaden its base to reduce the incentive to shift business activity to non-corporate forms; act towards rapid international agreement and take measures to prevent base erosion and profit shifting; eliminate regressive exemptions such as mortgage interest deductions for owner-occupied housing; simplify eligibility procedures for numerous (and often changing) tax provisions; reduce record keeping requirements when the tax authorities already possess the underlying information from other sources with a view to lower the cost of tax compliance and raise the efficiency of taxation; and increase reliance on consumption and environmental taxation." OECD (2016b) reports on actions taken recently, which do not involve any large change in fiscal policy, but include extended tax credits for R&D (Chapter 7), expensing for small businesses and a number of tax credits targeted at low-income households. US participation in the OECD/G20 Base Erosion and Profit Shifting (BEPS) Project is also noted.

Summary

- The United States has one of the least restrictive set of product market regulations among OECD countries. Businesses operate in a competitive environment conducive to investment, with little state control or public ownership of industries, and effectively no state ownership of commercial farms, and virtually no state ownership of food processing firms.
- With a few exceptions, US agricultural policy places few restrictions on entry, exit, production, and structural adjustment in farming. Marketing orders remain for over twenty commodities, but only one utilises volume controls.
- US antitrust policy does not focus on market structure *per se*, but on the likely effect of mergers and other business practices on output, innovation, and ultimately prices in markets. The issue of concentration in food and agriculture attracts widespread attention, and the impact of concentration in US agricultural markets has been recently reviewed.
- Certain agricultural cooperatives have been granted limited immunity from the antitrust laws, permitting their members to jointly process, prepare for market, handle, and market their commodities, and to jointly purchase inputs.
- In the United States, land and water rights are regulated at the State level and vary by State depending on resource availability and pressure. The stringency of US environmental policy has increased since the 1990s, but remains lower than on average in OECD countries.
- There is some direct government regulation of farm practices on environmental grounds, but the country relies heavily on voluntary incentive programmes to address natural resource issues. Some programmes provide financial incentives to either retire land from crop production or adopt more environmentally benign practices on land that is in production, while others tie eligibility for agricultural commodity and insurance programmes to compliance with certain conservation practices.
- Federal agri-environmental regulation concerns mainly livestock production and manure management practices. While standards are set at federal level, enforcement is carried out by individual states. Larger animal feeding operations must have a comprehensive nutrient management plan that identifies site-specific practices. Consolidation of production in larger operations concentrates manure in fewer locations.
- Primary responsibility for programmes aimed at protecting animal and plant resources from agricultural pests and disease lies with USDA’s Animal and Plant Health Inspection Service (APHIS). APHIS acts to keep foreign pests and disease out of the country; to provide an emergency response when foreign pests and disease do enter the country; to control or eradicate major domestic pests and disease; to prevent the interstate spread of disease and pests; and to facilitate agricultural trade by attesting to the health status of outgoing animals. The funds appropriated to agricultural quarantine inspection are supplemented with user fees collected at ports of entry.
- Under the coordinated Framework for Regulation of Biotechnology, biotechnology products are regulated according to their characteristics and not their production methods, as any product. Following the regulations applying to pesticides, the EPA verifies the toxin produced by insect resistant plants is safe for the environment, and does not cause allergy in food. The FDA is responsible for regulating the safety of GE crops that are eaten by humans or animals. It considers most crops produced from GE seeds as “substantially equivalent” to crops produced from seeds without GE traits, unless the insertion of a transgene into a food crop results in the expression of foreign proteins that differ significantly in structure, function, or quality from natural plant proteins and are potentially harmful to human health. The APHIS regulates the importation, interstate movement, and field testing of GE plants and organisms that are or might

be plant pests: a regulated plant cannot be introduced into the environment, even for field testing, without APHIS authorisation. The agency enforces guidelines for field testing and for data to be collected and reported during testing. The coordinated framework is being reviewed to address regulatory gaps regarding contamination and to respond to biotechnology developments.

- Antibiotic drugs are used widely in US livestock production, for disease treatment and prevention, but also as growth promoters. The United States has long had regulations on testing for and controlling antibiotic residues in animal products. USDA agencies have responsibility for approving label claims made regarding meat products, including claims regarding antibiotic usage, and provide process verification services for animals raised according to certain specified production practices, including processes that forego antibiotics.

- As a competitive net exporter in many products, the United States has traditionally been open to trade. Import tariffs are relatively low, except for some agricultural commodities. In addition to being part of numerous bilateral agreements, the country participates in major regional trade agreements with Northern and Central American countries, and is in the process of negotiating transpacific and transatlantic partnerships. Barriers to trade and investment are close to OECD standards. US barriers to trade facilitation are particularly low and electronic data exchange is increasingly used to further reduce them, but there are significant restrictions on foreign mergers and acquisitions in certain sectors and on foreign provision of legal services. Some barriers to FDI exist as in other OECD countries, but not in agriculture and food. The United States attracts FDI but at a lower rate in recent years. In cumulative terms, FDI stock as a percentage of GDP is close to the OECD average. FDI is low in agriculture like in most countries, while stocks of FDI in food have almost tripled in recent years.

- The United States has a very large and well-developed financial sector that maintains close links to global financial markets. Access to loans and financial services scores among the OECD top-five performance. There is a diversity of financial intermediaries such as banks, pension funds, insurance companies, and investment funds, but commercial banks and the Farm Credit System (FCS) account for over 80% of all lending to the farm sector.

- The Farm Service Agency (FSA) of the USDA directly provides ownership and operating loans to family farmers, emergency loans for losses from natural disasters, and conservation loans to finance completion of conservation practices in an approved conservation plan, but FSA accounts for a very small share of farm sector debt (2% in 2014). FSA direct loans and guarantees are directed to farmers who would not qualify for loans from commercial lenders, typically because they have little wealth and limited farming and credit experience. A share of direct loans is set aside for beginning farmers and ranchers and minority loan applicants.

- The United States has the highest corporate income tax rates among OECD countries, but a variety of special provisions narrow the base of corporate income that is subject to tax. This concerns most agribusinesses that are large corporations and taxed under the corporate income tax structure, but most farms are taxed under the individual income tax. Farmers benefit from both general tax provisions available to all taxpayers and from provisions specifically targeted to farmers. Some of the specific provisions that are responsible for this treatment include the current deductibility of certain capital costs, capital gains treatment of proceeds from the sale of farm assets, cash accounting, and farm income averaging. These and other provisions reduce the farm income tax base, allow some farm income to be taxed at reduced rates, and contribute to smoothing annual income variations.

Notes

1. Other farming practices can enhance resources and environmental quality by, for example, improving wildlife habitat or soil quality.
2. See section Regulations on Products and Processes.
3. Only very large livestock facilities with "manure management systems for livestock manure that emit equal to or greater than 25 000 metric tonnes CO2 equivalent per year (...) would be required to report emission estimates." (EPA, 2016).
4. The requirement is that using the pesticide according to specifications "will not generally cause unreasonable adverse effects on the environment", meaning "(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide, or (2) a human dietary risk from residues that result from a use of a pesticide in or on any food inconsistent with the standard under section 408 of the Federal Food, Drug, and Cosmetic Act."

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Chapter 5

CAPACITY BUILDING AND SERVICES FOR THE US FOOD AND AGRICULTURE SYSTEM

This chapter outlines the role of infrastructure capacity, skills and education in facilitating innovation in agri-food. It describes the governance of policies to improve rural infrastructure, outlines main regional programmes and reviews briefly the quality and coverage of rural services. It then discusses efforts to respond to skills demand from the agri-food sector through labour, immigration and education policy. It also reports on trends in education expenditure and outlines the performance of the education system. Finally, it provides an overview of education levels in agricultural and enrolment in agricultural programmes, outlining the gap between skills supply and demand in the sector.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Infrastructure and rural development policy

Investments in physical and knowledge infrastructure, from Information and Communications Technology (ICT) to transportation facilities, are important for overall growth and development. They are vital to the delivery of and access to important services and play a critical role in linking farmers and related businesses to markets, avoiding food waste, boosting agriculture productivity, raising profits, and encouraging investment in innovative techniques and products. Productive and profitable enterprises may have higher incentives to invest in sustainable practises that yield long term benefits.

Broader rural development measures also affect sustainable agricultural development and structural adjustment. Increased off-farm income and employment opportunities mitigate farm household income risks, facilitate farm investment, and enable a wider range of farm production choices. Improved rural services, from banking to ICT, are important to ensure needed connectivity to suppliers, customers, and collaborators. Rural policy can also attract innovative upstream and downstream industries, with possible spillover effects locally. By reducing inequalities in economic development and access to services across regions, rural development policies improve the diffusion of innovation.

US agriculture relies on an extensive physical infrastructure of transportation, communication, and electricity facilities, which have facilitated innovation in agriculture. Physical infrastructure relies on a mix of public and private ownership and financing, and federal, state, and local governments all play important roles in financing, regulating, and managing infrastructure.

US agricultural production is primarily carried out in rural areas. The US Government rural development programmes — primarily aimed at housing, economic development, health care, and infrastructure — therefore also affect agriculture, although the overlap between agriculture and rural America is far from exact. About 20% of nonmetropolitan counties, and less than 5% of metro counties, are also farming dependent counties, where agriculture accounts for at least 25% of the income generated in the county.

Physical infrastructure

According to the World Economic Forum's Global Competitiveness Report, the United States ranked 16th among 144 countries surveyed and 13th among OECD countries in 2015 in the overall quality of its transport, communications, and energy infrastructure. The United States ranks above average among all OECD countries in terms of the quality of its roads, railroad infrastructure, port infrastructure, air transport infrastructure, and electricity supply, but below the top-five OECD countries[1] on most of these indicators except air transport for which it ranks third (Figure 5.1). The quality of transport infrastructure has deteriorated since the crisis with the marked slowdown in the growth of public investment (OECD, 2016).

State and local governments make most decisions regarding infrastructure provision, with coordination arising when projects require several governments to act together as in the case of transport infrastructure (OECD, 2016).

The United States ranks slightly higher than the OECD average in the quality of electricity supply as assessed by a panel of executive leaders, and the number of fixed broadband subscriptions and fixed telephone lines per capita. However, fixed broadband communication is generally at lower speed and higher costs. The United States is below the average for OECD countries in the number of mobile telephone subscriptions per capita (Figure 5.2). Mobile telephone subscriptions per capita are much higher in the top-five OECD countries, but also in many less-developed countries. However, the United States has led the world in high speed Long-Term Evolution (LTE) mobile telephony that now covers over 95% of the continental territory. While Internet development has been mainly privately funded, recent federal programmes aim to enhance household Internet participation. Potential for greater competition is emerging in the fixed-line broadband sector with new entrants to the market beginning to create or augment existing networks, and posing potential competition challenges. In addition, some States impose prohibitions on municipalities creating their own networks.

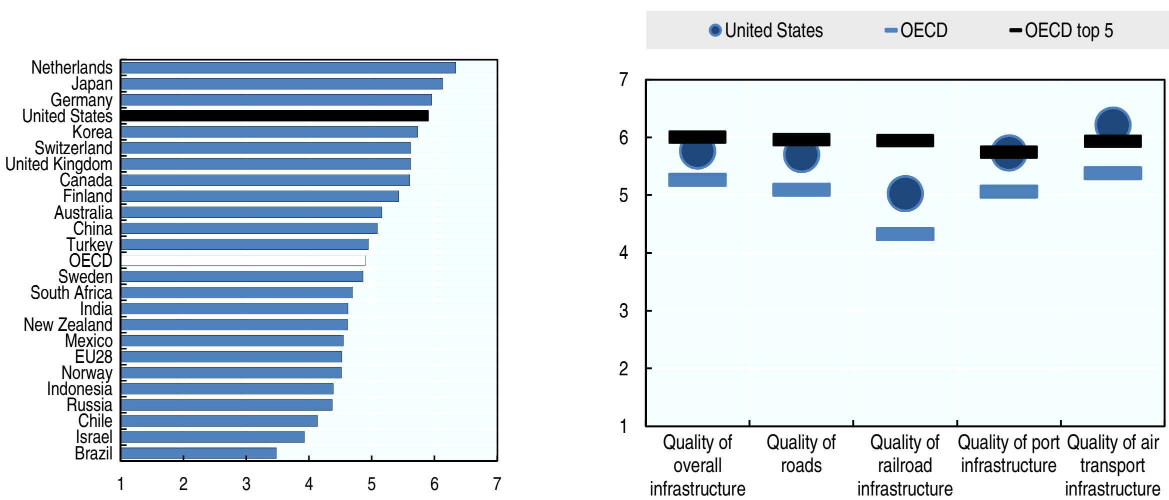
Access to infrastructure and urban centres varies greatly across the United States. For example, most of Alaska, much of the Mountain West and Great Plains regions, and substantial portions of the rural South, Central Appalachia, and Maine are at least a one-hour drive to the nearest urban centre of 50 000 or more (Figure 5.3). Access to all forms of infrastructure follows similar contours. For example, most of the eastern half of the country has access to fixed broadband connections, and virtually all of this region has access to wireless broadband (Figures 5.4 and 5.5). By contrast, most of Alaska and much of the rural West lack access to broadband service (especially fixed broadband).

Figure 5.1. Global Competitiveness Index: Quality of transport infrastructure, 2015-16

Scale 1 to 7 (best)

A. Index of transport infrastructure quality by country

B. US index of transport infrastructure quality by component



Indices for EU28 and OECD are the simple average of member-country indices.

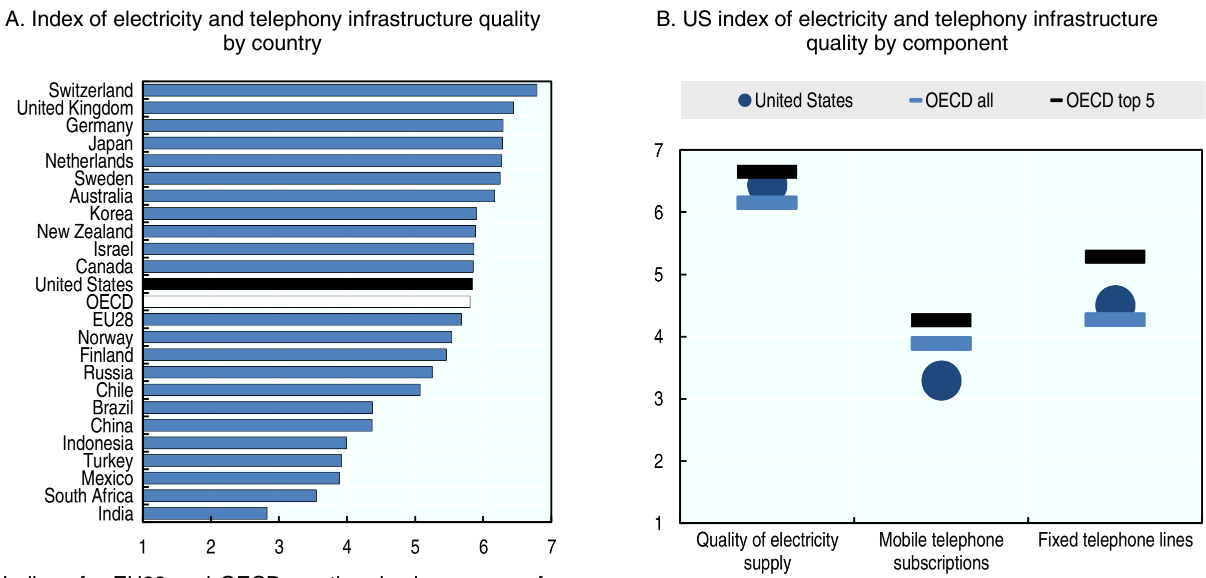
OECD top 5 refers to the average of the scores for the top 5 performers among OECD countries (Netherlands, Japan, Spain, France and Germany).

Source: World Economic Forum (2015), *The Global Competitiveness Report 2015-2016*, http://reports.weforum.org/global-competitiveness-report-2015-2016/.

StatLink http://dx.doi.org/10.1787/888933408572

Figure 5.2. Global Competitiveness Index: Quality of electricity and telephony infrastructure, 2015-16

Scale 1 to 7 (best)



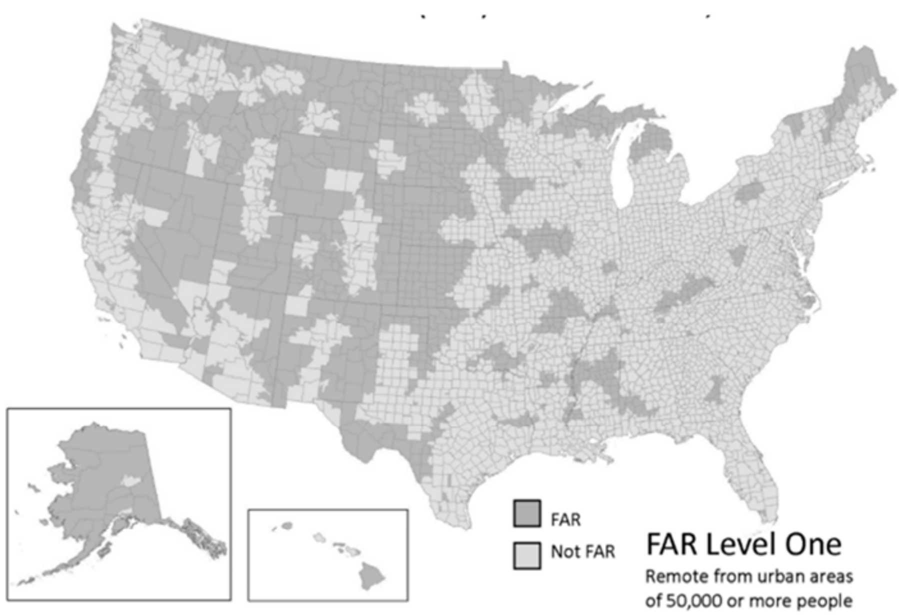
Indices for EU28 and OECD are the simple average of member-country indices.

OECD top 5 refers to the average of the scores for the top 5 performers among OECD countries (Switzerland, Luxembourg, Austria, United Kingdom and Iceland).

Source: World Economic Forum (2015), *The Global Competitiveness Report 2015-2016: Full data Edition*, http://reports.weforum.org/global-competitiveness-report-2015-2016/.

StatLink http://dx.doi.org/10.1787/888933408582

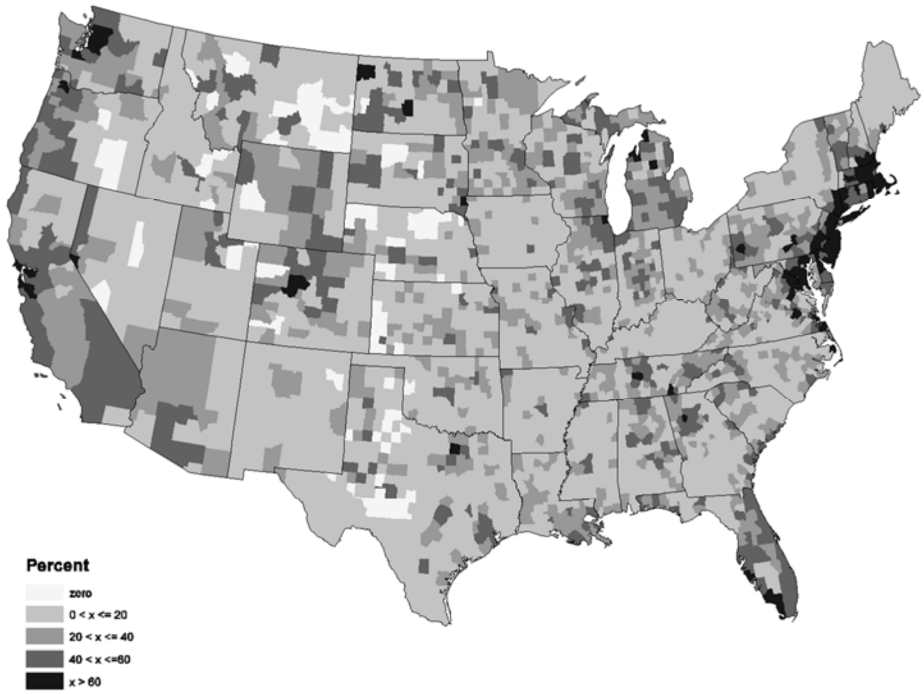
Figure 5.3. Access to urban areas, 2010



FAR level one includes ZIP code areas with majority populations living 60 minutes or more from urban areas of 50 000 or more.

Source: USDA Economic Research Service, using data from the US Census Bureau and ESRI.

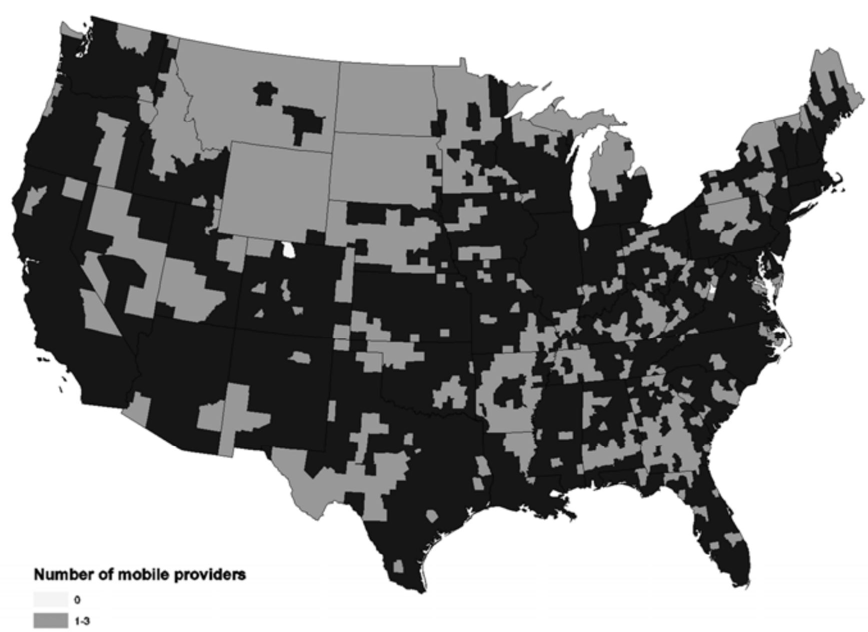
Figure 5.4. Fixed (wired) broadband access at 1.5 MBPS or greater, 2014



MBPS: megabits per second.

Source: USDA Economic Research Service, using data from the National Broadband Map, Federal Communications Commission.

Figure 5.5. Wireless broadband access at 1.5 MBPS or greater, 2014



MBPS: Megabits per second.

Source: USDA Economic Research Service, using data from the National Broadband Map, Federal Communications Commission.

Agricultural transportation

Because of the size of the country, and the often great distances between agricultural production regions, export ports, and domestic centres of consumption, investments in transportation have played an important role in the development of agricultural markets and in spurring investments in agriculture. Indeed, improvements in rail and ocean transportation, by reducing the costs of distance, played a critical role in the 19th century expansion of agriculture and settlement of the American West (Harley, 1978).

Almost all agricultural products, from grains to live chickens to milk, leave farms on trucks. Once they enter the transportation network, they may travel by truck, rail, water (usually barge), and even air. For example, just under half of cereal grains, by weight or value, moves from wholesalers, elevators, and other off-farm storage by truck, although these tend to be short-haul moves (Table 5.1). Long-distance shipments move by rail or, where available, by water.

Among other farm products, lower-value (per tonne) bulk commodities move by rail and by water for long-distance movements. Trucks carry higher value commodities, measured by value per tonne, often for short distances. Air is used for very high value perishable commodities — certain fruits and vegetables, for example — traveling long distances (Table 5.1 covers domestic shipments only). Live animals travel almost exclusively by truck, and typically for fairly short distances, while meat, poultry, and fish products also travel almost exclusively by truck, except for some very high value long-distance air shipments.

Table 5.1. Agricultural transportation: selected commodities and modes, 2012

Commodity class and mode of transportation	Value	Quantity	Value per tonne	Mean distance shipped
	Million USD	'000 tonnes	USD/tonne	Miles
Cereal grains				
All modes	130 140	479,064	272	202
Truck	62 606	224 475	279	94
Rail	48 004	184 749	260	670
Water	15 148	54 250	279	711
Farm products (excluding cereal grains, animal feed, forage products and livestock)				
All modes	197 793	218 995	903	505
Truck	145 612	135 713	1 073	182
Rail	14 154	26 720	530	1 189
Water	16 540	31 807	520	1 441
Air	1 159	139	8 338	2 135
Truck and Rail	9 931	15 212	653	778
Truck and Water	4 781	8 903	537	686
Live animals and live fish				
All modes	6 390	2 237	2 856	195
Truck	6 057	2 194	2 761	160
Meat, poultry, fish				
All modes	302 153	90 090	3 354	184
Truck	296 913	88 642	3 350	142
Air	864	72	12 000	2 692

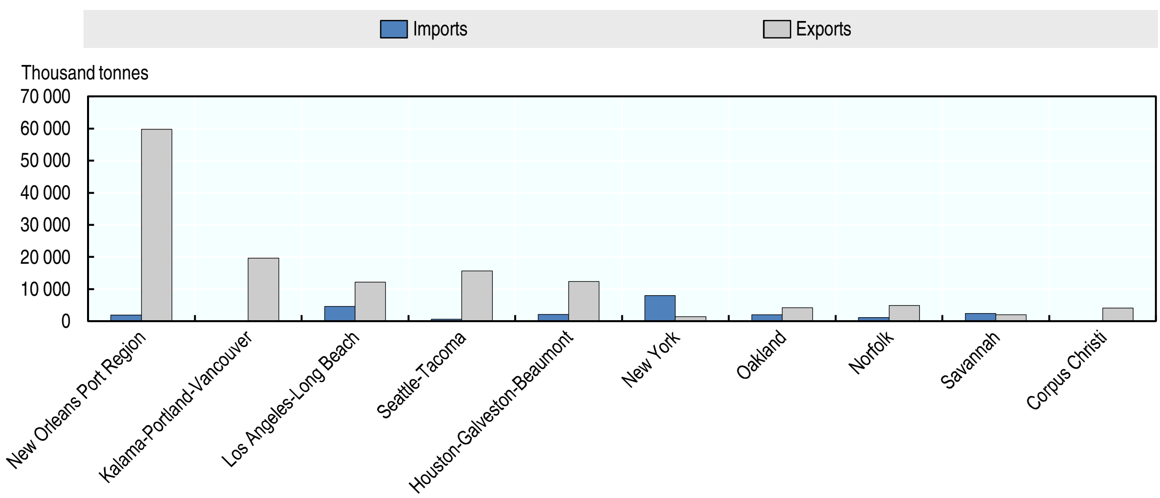
The survey covers domestic shipments originating in manufacturing or wholesaling establishments (such as grain elevators) but does not survey farms.

Source: US Census Bureau (2012), *Commodity Flow Survey*. www.census.gov/econ/cfs/.

Some US exports move by rail and truck to Mexico and Canada, and some high-value trade moves by air. However, most export tonnage moves through ports on the Atlantic, Pacific, and Gulf of Mexico coasts (Figure 5.6). The New Orleans port region, including locations and facilities along the Mississippi River near New Orleans, accounted for 40% of US agricultural exports by tonnage, primarily bulk commodities like grains and oilseeds bound for export. Pacific Northwest ports, including the Columbia River ports of Kalama and Vancouver in Washington, and Portland in Oregon, as well as Seattle and Tacoma on Puget Sound in Washington, accounted for another 24%. The New Orleans and Columbia River ports are served by inland waterways as well as railroads, making them ideal venues for bulk exports.

Thus the United States relies heavily on an effective railroad and waterway network for the long-distance movement of bulk commodities, especially grains, from elevators to ports for export. Trucks move farm commodities to nearby processing plants and elevator/storage facilities, and they move food products from processing plants to distributors and retailers. A well-maintained highway network is essential for these movements.

Figure 5.6. Ten largest US ports by volume of agricultural trade, 2011



Source: USDA (2015), Agricultural Marketing Service. http://dx.doi.org/10.9752/TS041.04-2010.

StatLink http://dx.doi.org/10.1787/888933408591

Infrastructure development policies

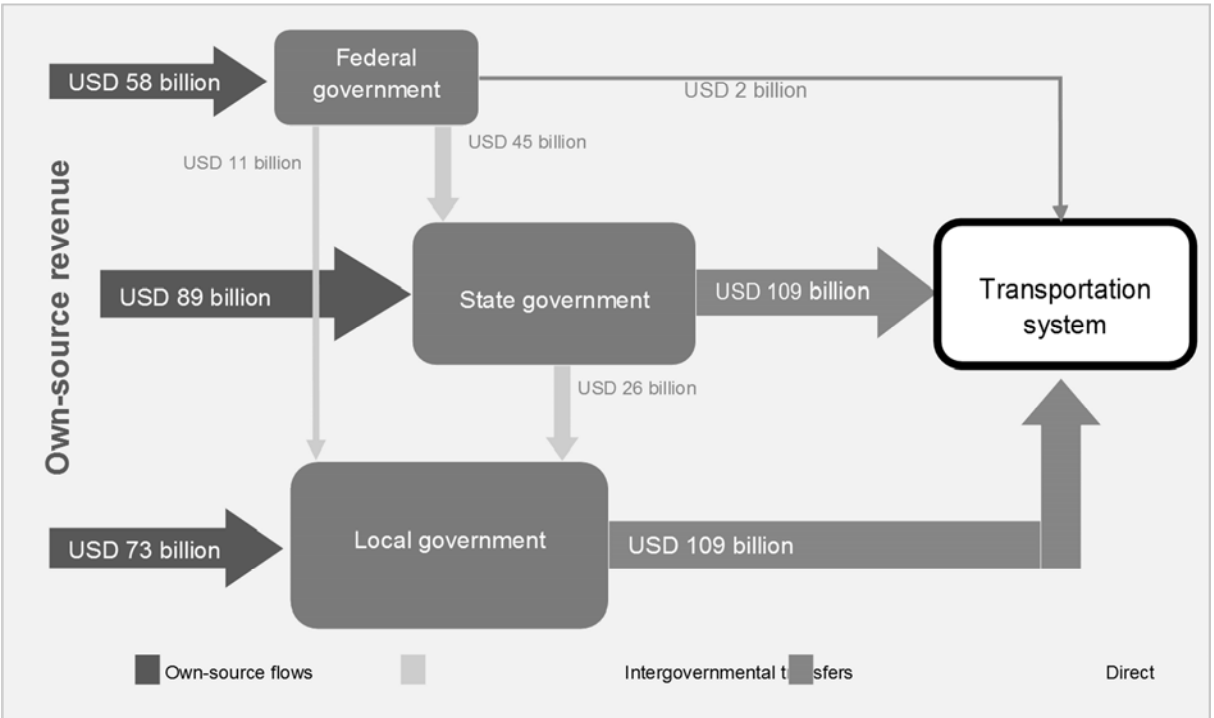
Many different levels, agencies and programmes of government, as well as the private sector, are involved in development of different forms of infrastructure.

Highways and transit systems

In 2012, the Federal Government spent USD 58 billion for investments in highways and transit systems, while state governments spent USD 89 billion, and local governments (counties, cities and towns, and local public agencies) spent USD 73 billion (Figure 5.7). About half of the total funds for highways are used for capital investments, with the rest used for maintenance, highway and traffic services, highway safety, administration, and debt service.

Almost all funds spent by the Federal Government for highways were provided via transfers to state governments or local governments through the federal-aid Highway Program administered by the Federal Highway Administration (FHWA), while states also transferred USD 26 billion to local governments. The Interstate Highway System — a network of controlled-access, high speed roads that criss-crosses the country — is partly funded by the Federal Government but owned and maintained by state governments. The Interstate System, which encompasses 47 856 miles of roads, accounted for one-quarter of all vehicle miles driven in the country. Local governments own and operate about 75% of the highway mileage in the United States. There are a few private toll highways and many private roads in the United States.

Figure 5.7. Spending on highways and transit by levels of government, 2012



Source: Pew Charitable Trust, www.pewtrusts.org/en/research-and-analysis/analysis/2015/02/24/funding-challenges-in-highway-and-transit-a-federal-state-local-analysis.

The primary source of revenue for federal and state spending on highways is the gasoline tax. Gas tax revenues of both the federal and state governments have declined over the past decade, due to changing driving habits, increased fuel efficiency of vehicles, and the fact that the federal gas tax and many state gas taxes are levied per gallon and have not increased for many years. The federal government and several states are increasingly relying on other sources of revenue to finance highway development, maintenance, and improvement, such as tolls, general funds, and bonds.

Despite declining revenues from gasoline taxes, the safety and conditions of highways and bridges generally improved between 2000 and 2010, although improvements have not been uniform as investments have targeted highways with greater traffic. For example, the share of rural interstate bridges classified as structurally deficient rose from 4.0% in 2000 to 4.5% in 2010, while the share of bridges in the entire National Highway System classified as structurally deficient declined from 23.7% to 21.4%.

Railroads

Most of the railroad tracks were built by private railroad companies in the 19th century using land grants from the federal government, and these companies and their successors still own and maintain the tracks and operate freight services on them. Railroads are used primarily to haul freight, and intercity passenger train traffic is limited mostly to the Northeast corridor between Boston and Washington. In 2010, US freight trains hauled more freight (in tonnes) than all of the European Union and hauled nearly eight times the number of tonne-miles of freight (Furtado, 2013). Most passenger trains, which are operated by public agencies, use tracks owned by freight railroad companies.

Railroad companies are subject to various federal and state government regulations, but maintenance and improvements of railroad infrastructure are financed out of their own resources. This affects the competitiveness of railroads relative to trucks and barges as modes of hauling freight, since investments in highways and waterways are largely publicly financed (US General Accounting Office, 1991).

The Staggers Rail Act of 1980 was the culmination of a series of major regulatory reform initiatives in airlines, trucking, pipeline and rail transportation during 1975-80, and presaged later reforms in electricity and telecommunications. The Act relaxed regulation of rail rates, primarily by allowing railroads and shippers to negotiate contracts for transportation, and provided railroads with greater flexibility in providing services and abandoning track. The reforms tied rail rates more closely to shipment sizes and volumes of traffic, which affected rail costs, and the resulting rate structure induced shippers to aggregate shipments into larger shipments on mainlines, and to shift to trucks for short-haul shipments. After passage of the Act, the size of the network contracted as railroads abandoned secondary lines, and railroad employment fell, but output rose and various measures of productivity rose sharply (Gallamore and Meyer, 2014). Real rates fell, and railroads expanded investments in track and facilities, leading to improved services as well.

Agricultural shippers — primarily grain shippers but also shippers of fertiliser and agricultural chemicals for sale to farmers, realised lower rates for longer-haul and larger shipments, and they responded by reorganising rail shipments to realise economics of scale (MacDonald, 1989). However, in some parts of the country — particularly in the Northern Great Plains — agricultural shippers are distant from the competition that waterways offer to railroads, and mergers have reduced to number of competing railroads to just one or two. The option of using long-haul, albeit high-cost, truck transportation constrains the rates that railroads can charge, but they nonetheless have market power and the issue of rail competition remains an important one for agricultural shippers.

Ports and waterways

The US Army Corp of Engineers (USACE) is the primary agency responsible for constructing and maintaining investments in the nation’s inland waterways and deep-water port facilities, including harbours, locks, canals, dams, levees, and other investments. The USACE operates and maintains 25 000 miles of navigable inland waterways in 41 states. The President’s Budget for Fiscal Year (FY) 2016 requested USD 4.7 billion for USACE’s Civil Works programmes, including about USD 1 billion for inland waterways and USD 1 billion for coastal waterways.[2]

High volumes of US agricultural exports move through the New Orleans Port Region (Figure 5.6), and most of that arrives at ports on barges moving through the Mississippi River System. In turn, much of the grain traffic originates on the Upper Mississippi River and the Illinois Waterway, which flows into the Mississippi. Navigation on each depends on a set of locks, and on water depth and flow in the rivers, which are partly influenced by public investments. Waterway navigation has also created ecological costs along the rivers, which the USACE is attempting to address (Casavant et al., 2010). A small amount of traffic also flows along the Missouri River, where management of water levels impacts recreational, environmental, hydroelectric power, flood control, and navigation uses. Management of Missouri River water levels is critical to Mississippi River traffic, because the Missouri system can store water for later release to the Mississippi, augmenting flows on that system. The USACE must balance a set of competing interests and investment options in managing navigation and water quality on the rivers.

Most of the funding for inland waterways comes from general funds, while a portion comes from the Inland Waterways Trust Fund, which is financed by a fuel tax levied on commercial users of waterways. Nearly all of the funding for coastal waterways comes from the Harbor Maintenance Trust Fund, which is financed by a tax on shippers, based on the value of commodities shipped through ports.

Other funds invested by USACE, such as investments for flood prevention and ecosystem restoration and stewardship, also contribute to the quality of waterways and ports.

The United States has 360 commercial ports, including more than 150 deep-draft seaports under the jurisdiction of 126 public seaport agencies. Seaport authorities develop and maintain terminal facilities for transferring cargo between different transportation modes. Public port authorities work closely with private industry to invest in terminals and other maritime facilities.

Airports

Almost all commercial airports in the United States are publicly owned by local or state governments, or by public entities such as airport authorities or multipurpose port authorities (Tang, 2014). In 1996, Congress established the Airport Privatization Pilot Program (APPP) to promote privatisation of airports, but by 2014 only two airports had privatised (via long-term leases of the airport to a private company), and one of those — Stewart International Airport in Newburg, NY — reverted to public ownership in 2007.

Although almost all commercial airports are publicly owned, private companies play major roles in their management, financing and operation. Private airline companies lease space in airport terminals, and in some cases are involved in financing terminal improvements. As lessees of airport facilities, airline companies also can have substantial influence on airport investments. Private companies are also usually involved in providing airport services, such as parking garages, cleaning services, restaurants, and other services.

The Federal Government plays a major role in regulating airport operations and safety through the operations of the Federal Aviation Administration. Through the Essential Air Service programme, the Department of Transportation subsidises commercial airline services to rural communities that were served by airlines prior to airline deregulation and that otherwise would not be served.

Electricity

Most electricity is generated by private investor-owned utilities. The remainder is generated by municipal public utilities, cooperatives, federal power marketing agencies such as the Tennessee Valley Authority and the Bonneville Power Administration, state power marketing agencies such as the New York Power Authority, and private nonutility power producers. Nonutility power producers do not distribute electricity to final consumers; they sell electricity to electric utilities or to power marketers.

Historically, most investor-owned electric utilities were vertically integrated monopolies, involved in electric power generation, transmission (the movement of electricity from power plants to transformer substations in high voltage lines), and distribution (the movement of electricity from substations to consumers in low voltage lines). The retail prices charged by investor-owned electric utilities to consumers have long been regulated by state public utility agencies, while interstate wholesale prices for electricity are regulated by the Federal Energy Regulatory Commission (FERC).

Transmission lines are owned by investor-owned utilities, electric cooperatives, publicly-owned utilities, regulated transmission owners, and transmission merchant companies (Brown and Sedano, 2004). The transmission grid in the United States and Canada is divided into five subsystems, called interconnections, including one in the western United States and Canada and northern Baja California, one in the eastern United States and parts of Canada, one in Quebec and parts of the north-eastern United States, one in Texas, and one in Alaska. These interconnections transmit synchronised alternating current (AC) electric power within each subsystem, but are not synchronised with each other. Transmission between these systems requires conversion of AC power to direct current (DC) and then reconversion to AC requiring expensive equipment. Hence most electric transmission occurs within these interconnections; as there is limited capacity for transmission between them.

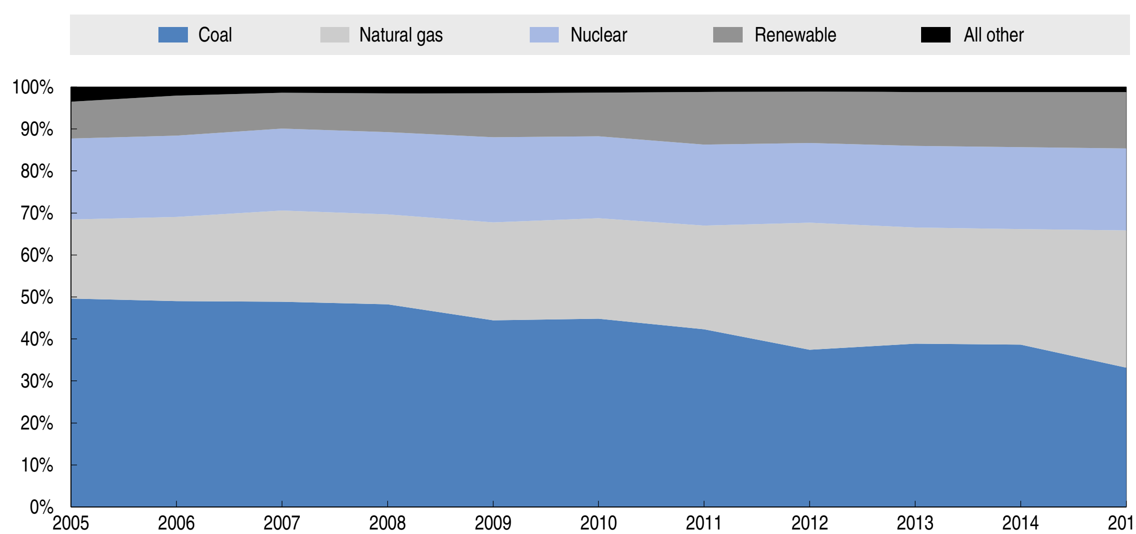
The reliability of the eastern interconnection is managed by several regional reliability councils, while each of the other interconnections has a single reliability council. Operation of the transmission grid is regulated by the North American Electric Reliability Corporation (NERC), a not-for-profit international regulatory authority, subject to oversight by FERC and government authorities in Canada. Non-discriminatory access to the transmission grid is controlled by a system of Regional Transmission Operators (RTOs) and Independent System Operators (ISOs) that are independent of power generators and utilities, and regulated by FERC.

The integrated and regulated industry structure has gradually changed in recent decades (Joskow, 2000). A deregulated wholesale market in electricity sales among utilities began to develop in the 1970s, and independent power producers began to enter the generation market and sell to utilities in the 1980s. After enactment of the Energy Policy Act of 1992, several states pursued deregulation of the electric industry, under which wholesale prices would be fully deregulated, and some types of retail prices would also be deregulated. As of January 2016, 16 states and the District of Columbia had deregulated electricity markets, while 7 states have suspended deregulation efforts. Concerns about manipulation of electricity supplies and prices, as occurred after a partial deregulation in California, may have limited wider adoption of deregulation.

Electricity generation has undergone another important shift in recent years: the movement away from coal as a fuel source and toward natural gas and wind power (Figure 5.8). A decade ago, half of US electricity generation was powered by coal, while natural gas accounted for less than a fifth. In 2015, coal and natural gas each accounted for one third, while the share of renewables rose from 9 to 14%, largely through the expansion of wind sources. The shift to natural gas has in turn been driven by new domestic production facilitated by fracking technologies, which have sharply reduced natural gas prices.

Figure 5.8. US electricity generation, by fuel source, 2005-15

Net generation by utility scale electric generation facilities (million megawatt hours)



Source: US Department of Energy (2016), www.eia.gov/.

StatLink http://dx.doi.org/10.1787/888933408604

Changes in the electricity sector, particularly in generation, have provided some new opportunities for US farmers. Almost 97 000 farms received income from energy leases (natural gas, oil, or wind) in 2014, with a median annual payment of nearly USD 6 000. Most of the recipients leased land for the placement of wind turbines. There has also been interest in the use of anaerobic digesters on dairy and pig farms, to capture methane gas from manure for use either for on-farm electricity generation or for sale to utilities as a feedstock for commercial electricity production (Key and Sneeringer, 2011). Digesters are privately profitable only for very large farms with willing buyers of excess electricity production. However, there is considerable policy interest in supporting them — through capital subsidies, direct payments, or renewable fuel purchase mandates imposed on utilities — as a way to reduce greenhouse gas emissions. By 2014, 35 swine and 244 dairy farms had adopted digesters; the dairy adopters tended to be quite large, representing about 5.6% of the national inventory of milk cows.

Telecommunications

Telecommunications includes information and communication technologies (ICT) — telephone, telegraph, computers, cable TV, mobile phones, radio, other electronic devices, and the Internet. In the United States, these technologies are provided by private industry that ranges from large private corporations to small member-owned rural cooperatives (and number into the thousands), with a few municipally-owned operations in the mix.

The industry is regulated under the Communications Act of 1934, which has been amended over the years. The last major revision took place under the Telecommunications Act of 1996. The law sets out the role of the federal, state, and local governments and covers most aspects of the ICT industry. The 1934 Act mandates and instructs the Federal Communications Commission's regulatory authority over the industry, except where state and local government has authority. Each of the 50 states has a public utility commission that regulates the state's industry within the scope allowed under the 1934 Act.

Historically federal, state, and local government telecommunication infrastructure programmes have mostly leveraged private funds to increase the availability of communication service, but recently some programmes have been designed explicitly to increase household Internet participation. The Rural Utility Service (RUS) of the US Department of Agriculture (USDA) has been the lead agency for rural Internet policy and has three on-going Internet programmes: 1) traditional federal Rural Telecommunication Infrastructure Program requiring all facilities to be broadband capable; 2) farm bill Rural Broadband Program (authorised by the five-year farm bills, the Agriculture Act of 2014 is the latest of these); and 3) Community Connect Broadband Grant Program.

The US Department of Commerce's National Telecommunications and Information Administration (NTIA) and RUS also jointly administered broadband programmes resulting from the American Recovery and Reinvestment Act of 2009 that has led to, approximately, a USD 7 billion investment in broadband infrastructure. Recently the Federal Communications Commission (FCC) reformed the Universal Service Fund and created the Connect America Fund that provided USD 300 million in phase I monies for private investment in rural broadband system development. In September 2015 the FCC announced a further USD 9 billion over six years in phase II monies awarded to service providers. Although this is a substantial investment, it is less than one percent of all communication infrastructure investment in the country.

Regional development policies and programmes

Regional agencies such as the Tennessee Valley Authority (TVA), the Appalachian Regional Commission (ARC), the Delta Regional Authority (DRA), and the Denali Commission also are involved in infrastructure investment and other economic and community development activities.

The TVA is a corporate agency of the Federal Government established in 1933 to help improve the quality of life in the Tennessee Valley, a region that was hit hard by the Great Depression. The

Tennessee Valley region includes most of Tennessee, significant parts of Alabama, Mississippi, and Kentucky, and small portions of Georgia, North Carolina, and Virginia.

The TVA was the first large regional planning agency of the Federal Government. Its mandate was to promote navigation, flood control, electricity generation, fertiliser manufacturing, restoration of degraded lands, and economic development in the Tennessee Valley. TVA operates the nation's largest public power system. Dams and hydroelectric facilities were the initial focus of TVA's energy production, but by the mid-1950s coal surpassed hydropower as TVA's primary source of energy, and in the 1960s TVA constructed its first nuclear power plant. In 2015, about 40% of TVA's electricity production was from coal, 33% from nuclear, 13% from natural gas, 10% from hydropower, and 3% from renewables (TVA, 2015). In addition to electricity generation and distribution, TVA has programmes related to environmental stewardship and economic development. For example, TVA works with regional, state, and community organisations to offer site selection services, incentives, research and technical assistance to help companies locate and expand operations in the Tennessee Valley. TVA is financed by its own operating revenues, primarily from its sales of electricity, and by borrowing. In 2015 TVA's revenues were USD 11 billion and its expenses were about USD 10 billion (TVA, 2016).

The ARC was established in 1965 as part of President Johnson's War on Poverty to promote economic development in the impoverished Appalachian region, which includes all of West Virginia and parts of 12 other states. The ARC is a federal-state partnership in which the governors of the region's states have a role in selecting projects for funding, along with the Federal Government. The 1965 ARC Act appropriated funds for highways, hospitals and treatment centres, land conservation and stabilisation, land restoration, flood control and water resource management, vocational education facilities, and sewage treatment works. The ARC currently focuses on: 1) investing in entrepreneurial and business development strategies; 2) improving the education, knowledge, skills, and health of Appalachian residents; 3) investing in infrastructure — especially broadband, highways, and water/wastewater systems; 4) strengthening community and economic development potential by leveraging the region's natural and cultural heritage assets; and 5) building the capacity of leaders and organisations to innovate, collaborate, and advance community and economic development. The ARC is funded by annual appropriations from Congress, which are USD 146 million for 2016. It also seeks to leverage other public and private investments in the Appalachian region.

The Denali Commission was established in 1998 to address infrastructure, workforce, and economic development needs of remote communities in Alaska. Like the ARC, it is a federal-state partnership. It is funded by annual appropriations, interest on the Trans-Alaska-Pipeline-Liability Fund, and other federal funds; these funds amounted to about USD 24 million in 2014 (Denali Commission, 2015). The Denali Commission's programmes focus on investments in transportation and energy infrastructure, health facilities, training, and government coordination.

The DRA was established in 2000 to promote economic development in the impoverished Mississippi Delta region, which includes parts of eight states in the vicinity of the Mississippi River. Like the ARC, the DRA is a federal-state partnership and is funded by annual appropriations, which amounted to USD 12 million in 2015 (DRA, 2015). The DRA targets most of its grant funds to economically distressed communities, and focuses on investments in small business and entrepreneurship, workforce development and training, basic public infrastructure (such as water and sewer systems, electric and gas utilities, broadband delivery, and solid waste landfills) and transportation infrastructure. The DRA works in partnership with other federal and state agencies, seeking to leverage other sources of funds. Contributing to the potential leverage of DRA funds is the fact that that the DRA Act allows DRA funds to be used to supplement other federal programme funds above the maximum amounts of federal support authorised by other applicable laws (Pender and Reeder, 2011).

Several other regional development commissions have been authorised by Congress, including the Northern Border Regional Commission (NBRC), the Northern Great Plains Regional Authority, the Southeast Crescent Regional Commission, and the Southwest Border Regional Commission. Of these, only the NBRC has ever received appropriations, including USD 5 million in 2015.

The NBRC has been in operation since 2010, and focuses on grants to help address community and economic development needs of economically distressed areas of the northern forest region, which includes parts of Maine, New Hampshire, Vermont, and New York. NBRC grants focus on transportation and basic infrastructure, job skills training and entrepreneurial development, comprehensive strategy development, advanced technologies and telecommunications, and sustainable energy solutions. Like the DRA and other regional development commissions, the NBRC seeks to leverage other public and private investments with its limited amount of funds.

Several other federal initiatives have also promoted regional development, including:

- Empowerment Zones and Enterprise Communities (EZ/EC), established in the early 1990s and providing grants and tax incentives to promote development in selected high poverty urban communities and rural regions;
- Renewal Communities (RC), established in the 2000s with similar objectives to the EZ/EC programme, but limited to use of tax incentives to promote development in high poverty urban and rural RCs;
- Gulf Opportunity Zones (GO Zones), established after Hurricanes Katrina, Rita, and Wilma in 2005, to promote economic recovery and development in the regions affected by the hurricanes using tax incentives; and
- Place-based policies and programmes pursued by the Obama Administration without a need for authorising legislation, such as the Promise Zones initiative, which is targeted to high-poverty communities and provides preferential access to grants and technical assistance through selected federal government programmes.

Rural development policies and programmes

The USDA is the lead federal agency for rural development programmes, which are operated by USDA's Rural Development (RD) mission area. RD programmes seek to promote rural prosperity by providing direct and guaranteed loans, grants, and technical assistance to support development of rural businesses and cooperatives, utility infrastructure, and housing and community facilities through the Rural Business-Cooperative Service (RBS), the Rural Utilities Service (RUS), and the Rural Housing Service (RHS). Over the years, the share of assistance provided under grant and direct loan programmes has declined, while guaranteed loans have increased in importance. The total value of assistance (programme level) provided by RD programmes in 2015 was more than USD 38 billion (Table 5.2), with most of this in loans or loan guarantees. The budget authority (appropriations) required paying the costs of grants, unrecovered loans, salaries and expenses amounted to less than USD 3 billion in 2015.

By far the largest RD programme in terms of programme level is the Single Family Housing loan programme, which provided mortgage loans for single family dwellings in rural areas worth nearly USD 25 billion in 2015. However, almost all of these loans are expected to be repaid, so the budget authority required for the programme is only USD 66 million. The rural electricity programmes are the largest RD programmes to support investment in utility infrastructure (USD 5.5 billion programme level in 2015), but all of these loans are expected to be repaid by rural utilities, so no budget authority is required for these.

The largest RD programme in terms of budget authority is the Rental Assistance grant programme, costing over USD 1 billion in 2015. Rental Assistance payments are used to reduce the rents of low income families in multi-family rural housing projects financed by RHS loans to no more than 30% of their income. Other relatively large (in terms of budget authority) RD programmes include the Water and Waste Disposal Program (which provides financing for rural communities to establish, expand or modernise water treatment and waste disposal facilities), the Business and Industry Guaranteed Loan Program (which guarantees up to 90% of the value of loans by commercial lenders to rural businesses), and the Rural Energy for America Program (which supports the President's Climate Action plan by providing financing for the purchase of renewable energy systems, energy efficiency improvements, energy audits and feasibility studies).

Table 5.2. USDA rural development: Enacted programme levels and budget authority, 2015

Million USD

Agency	Programme	Total programme level	Budget authority
RBS	Business and Industry Guaranteed Loans	920	47
	Rural Business Development Grants	24	24
	Rural Economic Development Loans/Grants	43	0[3]
	Value-added Producer Grants	11	11
	Rural Energy for America Program	88	47
	Biorefinery Assistance Guaranteed Loans	71	30
	Bioenergy for Advanced Biofuels	14	14
	Other RBS programmes	22	17
	Salaries and expenses	4	4
	Subtotal – RBS	1 216	200
RUS	Electricity Programs	5 500	0
	Telecommunications Programs	690	0
	Distance Learning and Telemedicine Programs	22	22
	Broadband Programs	34	15
	High Energy Costs Grants	10	10
	Water and Waste Disposal Programs	1 705	455
	Salaries and expenses	35	35
	Subtotal – RUS	7 996	537
RHS	Single Family Housing Loan Programs	24 900	66
	Multi-Family Housing Loan Programs	178	10
	Very Low-Income Repair Grants and Loans	55	33
	Farm Labor Housing Grants and Loans	32	16
	All Other Direct Housing Loans	20	0
	Rental Assistance Grants	1 089	1 089
	Community Facilities Loans and Grants	2 299	30
	Other RHS Programs	66	55
	Salaries and expenses	415	415
	Subtotal – RHS	29 054	1 714
	Salaries and expenses at RD level	224	224
	Total Rural Development	38 490	2 675

RBS is Rural Business Services; RUS is Rural Utilities Service; and RHS is Rural Housing Services. 2015 is fiscal year (FY) 2015.

Source: USDA (2016), USDA FY 2017 Budget Summary. www.obpa.usda.gov/budsum/fy17budsum.pdf.

Many other federal agencies also provide assistance to rural communities through various programmes, including programmes of the Department of Transportation (DOT), the Small Business Administration (SBA), the Commerce Department (especially the Economic Development Administration), and many others. In 2005, the US Government Accountability Office (GAO, 2006) reviewed 86 Federal Government programmes in ten federal agencies and three regional commissions that provide economic development assistance. GAO found that these programmes provided in total (to both urban and rural areas) about USD 200 billion in funding from 2002 to 2004, with the largest share of funds to rural areas provided by programmes of USDA, Department of Interior, and the regional commissions, while the largest amount of funds was provided to rural areas by DOT programmes, followed by USDA programmes. Although a smaller share of funds went to rural areas under DOT programmes than under USDA programmes, the total volume of funds provided under DOT programmes was substantially larger.

State and local governments also influence rural development through various programmes, investments and tax incentive policies. Some states provide specific incentives to promote business investments in rural areas. For example, Florida offers increased incentive awards and lower wage qualification thresholds through its business incentive programmes for businesses investing in its rural counties, and also operates a Rural Community Development Revolving Loan Fund and a Rural Infrastructure Fund to help address special needs that business face in rural areas.

Labour market policy

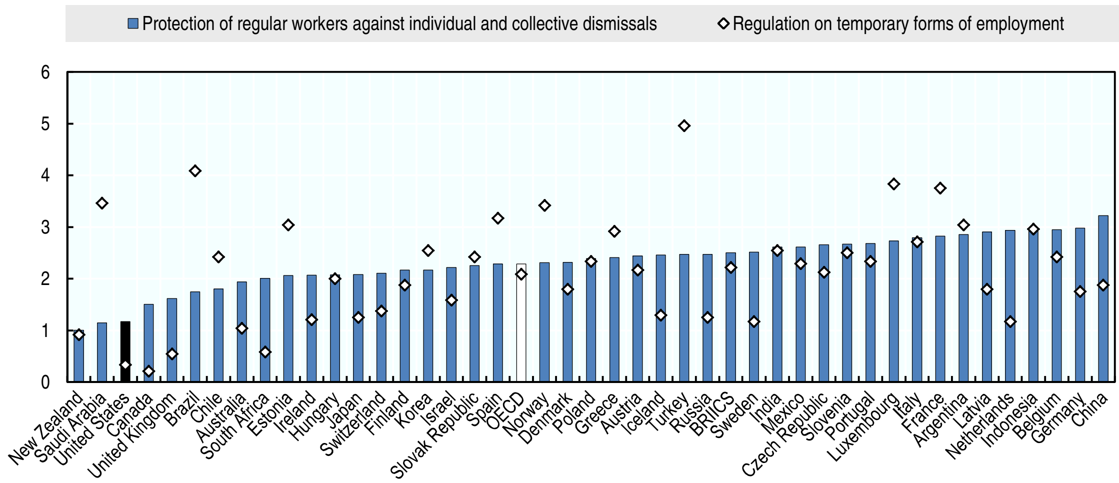
Public policies affect the size, flexibility, and skills of the workforce available for agriculture. Government labour market policies affect the ease with which workers can move into and out of agricultural employment as well as the conditions of employment. It thus influences employment composition and labour mobility, in particular by facilitating (or discouraging) labour to adapt to new circumstances. It can play an important role in facilitating structural adjustment, including farm consolidation, by assisting excess labour in farming to exploit more remunerative non-farm income and employment opportunities. Policies on skills improvement and on international mobility of human resources can affect innovation and knowledge transfer through exchange of skills and skilled labour. Structural adjustment allowing younger and better educated farmers to enter the sector, and skills improvement policies are expected to improve the adoption of sustainable practices.

Labour market legislation and efficiency

The United States has one of the least restrictive employment protection legislation among G20 countries, in particular for temporary forms of employment (Figure 5.9). As a result, the US labour market is ranked by business leaders as one of the most efficient in the OECD area (Figure 5.10A). This gives the agri-food sector the flexibility to adjust quickly to changes in labour and skills needs. Business leader opinion surveys place the US labour market among the top five performers in most criteria, in particular the capacity to attract and retain talent (Figure 10B). This is particularly important for agricultural innovation as the US innovation system attracts well-qualified nationals and foreigners.

Figure 5.9. OECD indicators of employment protection legislation 2013[1]

Scale from 0 (least) to 6 (most) restrictive



The OECD Indicators of Employment Protection refer to labour market flexibility regarding the procedures and costs required to dismiss workers and the procedures involved in hiring workers.

Data for Argentina, Brazil, China, India, Indonesia, Russian Federation, Saudi Arabia and South Africa represent 2012.

Source: OECD (2014), Employment Protection Database. www.oecd.org/employment/protection.

StatLink http://dx.doi.org/10.1787/888933408619

The general employment legislation affects agribusiness companies, but also the farming sector to the extent many farmers pursue off-farm work, even those who operate large farms. One third of the principal operators of farms with between USD 500 000 and USD 1 000 000 in sales worked off the farm in 2012, and 27% of principal operators with at least USD 1 000 000 in farm sales. Moreover, many farm spouses hold off-farm jobs. Consequently labour market policies that cover all industries also matter to farmers.

Some labour market policies are of specific interest to agriculture. In 1948, 8 million people were employed in US agriculture — about 12% of total civilian employment. Then, and for years thereafter, labour-market related policies included policies to ease the transition of farmers and farm workers into non-farm employment. However, that sectoral transition was largely completed by the 1970s, and agricultural employment has been steady for the last decade. In addition, there are specific laws regulating the terms and conditions of agricultural employment (see below).

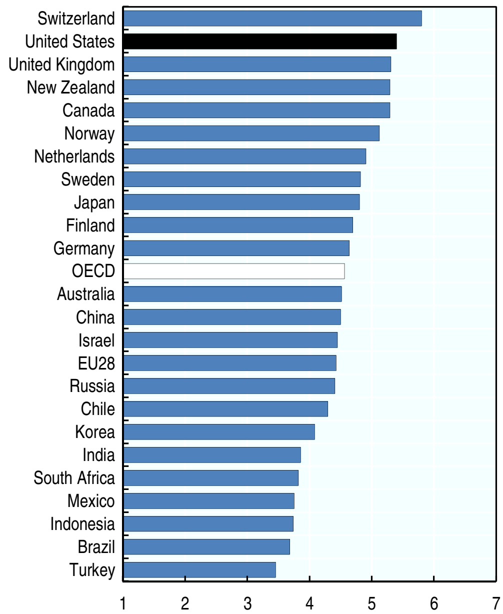
Today, the sector employs about 1 million full-time equivalent wage and salary workers (including those directly hired and those brought to farms by labour contractors). In addition, there are about 3 million farm operators who do not draw a wage or salary; most of these operate very small farms, but their full-time equivalent employment amounts to 1.57 million workers (using a definition of full-time equivalent of 2 040 hours per year).

About half of all hired farm workers, and as many as three-quarters of hired crop farm workers, are foreign-born. As a result, immigration policies matter for agriculture. Policies that encourage the development of labour-saving technologies also matter, and are intertwined with immigration policy.

Figure 5.10. Global Competitiveness Index: Labour market efficiency, 2015-16

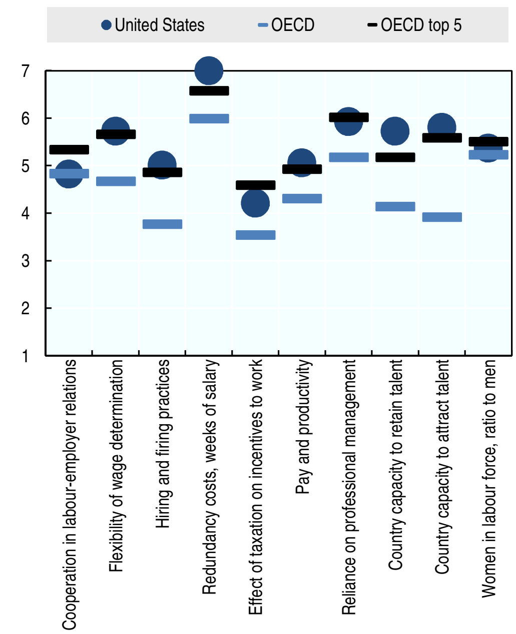
Scale 1 to 7 (best)

A. Index of labour market efficiency by country



Indices for EU28 and OECD are the simple average of member-country indices.

B. US index of labour marker efficiency by component



OECD top 5 refers to the average of the scores for the top 5 performers among OECD countries (Switzerland, United States, United Kingdom, New Zealand and Canada).

Source: World Economic Forum (2015), *The Global Competitiveness Report 2015-2016: Full data Edition*, Geneva 2015. www.weforum.org/reports/global-competitiveness-report-2015.

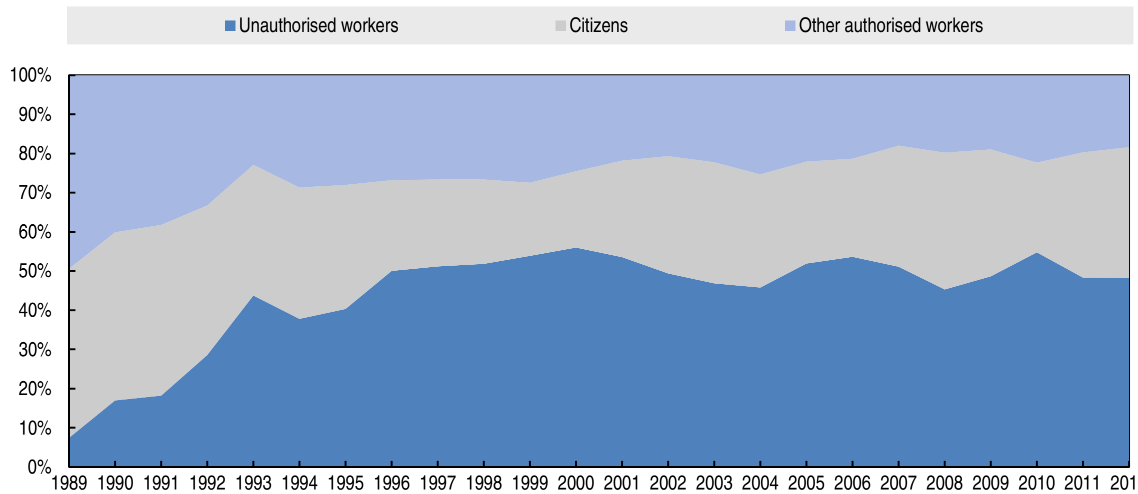
StatLink http://dx.doi.org/10.1787/888933408621

Immigration policy with implications for agriculture: Programmes and utilisation rates

Unauthorised immigrants, primarily from Mexico, but increasingly from Central America, provide roughly half of hired labour services to crop agriculture, and an unknown but significant share of labour services in livestock, especially on dairy farms. The level of enforcement at the border and in the interior influence the size of this pool of unauthorised workers as do demographic and economic trends in sending countries. The share of unauthorised workers in the total hired labour crop workforce grew sharply between 1993 and 2000, and has since remained stable (Figure 5.11).

The importance of unauthorised workers varies across crops (Figure 5.12). They accounted for 22% of hired workers in field crops in 2005-09, while US citizens account for 64%. At the other extreme, unauthorised workers accounted for 61% of hired workers on vegetable farms and 67% of those on fruit farms.

Figure 5.11. Trends in authorisation status of hired US crop workers, 1989-2012



Source: USDA Economic Research Service analysis of US Department of Labor (2015), National Agricultural Workers Survey www.doleta.gov/agworker/naws.cfm.

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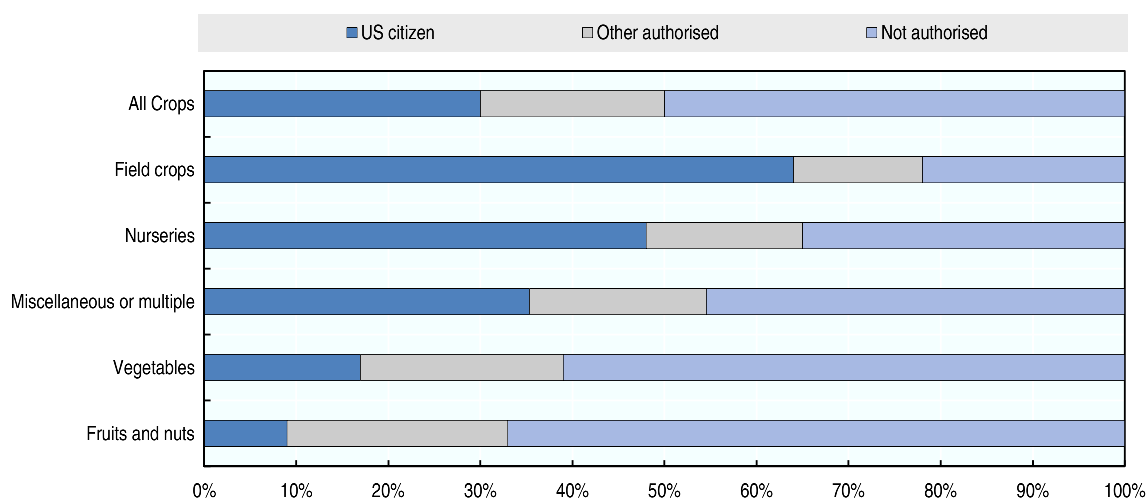
Figure 5.12. Unauthorised workers account for half of all hired labour on crop farms, 2005-09



Source: USDA Economic Research Service analysis of US Department of Labor (2015), National Agricultural Workers Survey, 2005-09. www.doleta.gov/agworker/naws.cfm.

StatLink http://dx.doi.org/10.1787/888933408644

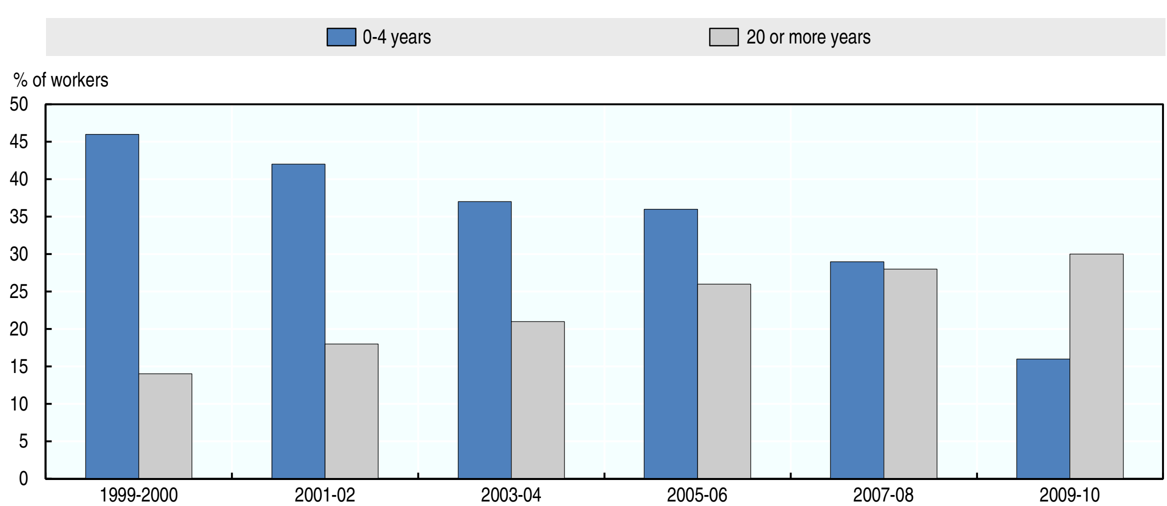
The nature of the hired farm work force has changed since 2000, due to new immigration laws, more vigorous enforcement of immigration laws, and changes in the incentives to migrate from Mexico. Policy was strongly affected by the September 2001 attacks on the United States. The states of Alabama, Arizona, Georgia, Mississippi, North Carolina, South Carolina and Utah now require almost all private employers to verify legal immigration status via a federal online system as a condition of employment; many other states have imposed this requirement for state and local governments or their contractors, or otherwise strengthened immigration status documentation requirements.

Net migration slowed in the 2000s, so that the hired farm workforce became older and more settled. There was some decline in foreign-born workers, from 83% of hired workers in 1999-2000 to 71% in 2011-12. But the foreign born workforce also became older and more stable. Among foreign-born farm workers in 1999-2000, 46% reported migrating within the last four years, while 14% reported being in the country for at least 20 years (Figure 5.13). The share of recent immigrants fell steadily over the next decade, reaching 16% in 2009-10, while the share of long-term immigrants rose to 30% by 2009-10.

In addition, the patterns of migration shifted. The number and share of hired crop workers who migrate during a year, either from farm-to-farm ("follow the crop"), or from home-to-farm ("shuttlers"), fell sharply (Figure 5.14). The fractions settled in one place rose from 42% of the workforce in 1998 to 74% by 2009. In particular, unauthorised follow-the-crop migrants were less willing to move farm-to-farm because of the risks of discovery and deportation (Fan et al., 2015).

These changes in the hired workforce led to concerns among some growers about labour supply: in particular, fruit and vegetable growers rely on migrant workers to meet sharp seasonal fluctuations in the tempo of work. These concerns led them to seek political accommodation through changes in policy through an expanded programme for temporary authorised workers; however, no new programme has been passed.

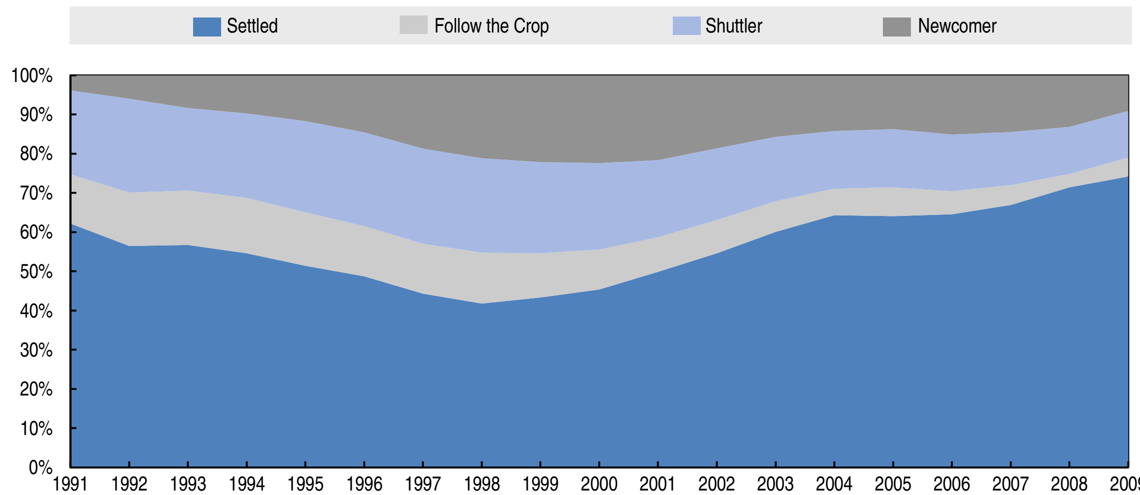
Figure 5.13. Number of years since foreign-born agricultural workers have migrated, 1999-2000 to 2009-10



Source: US Department of Labor (2015), National Agricultural Workers Survey, 2005-09, www.doleta.gov/agworker/naws.cfm.

StatLink http://dx.doi.org/10.1787/888933408656

Figure 5.14. Migration patterns for hired US crop workers, 1991-2009



The figure shows three-year moving averages, e.g. 1991=1990-92 average.

Source: US Department of Labor, National Agricultural Workers Survey. www.doleta.gov/agworker/naws.cfm.

StatLink http://dx.doi.org/10.1787/888933408662

The H-2A non-immigrant programme is designed to provide US farms with short-term agricultural labour when the number of available domestic workers is insufficient. H-2A labour certification is generally granted for activities lasting 10 months or less. Employers must perform recruitment activities to establish that US workers are not available, and successful applicants must pay transportation and housing costs for their workers, and abide by a regionally-specified minimum hourly wage rate.

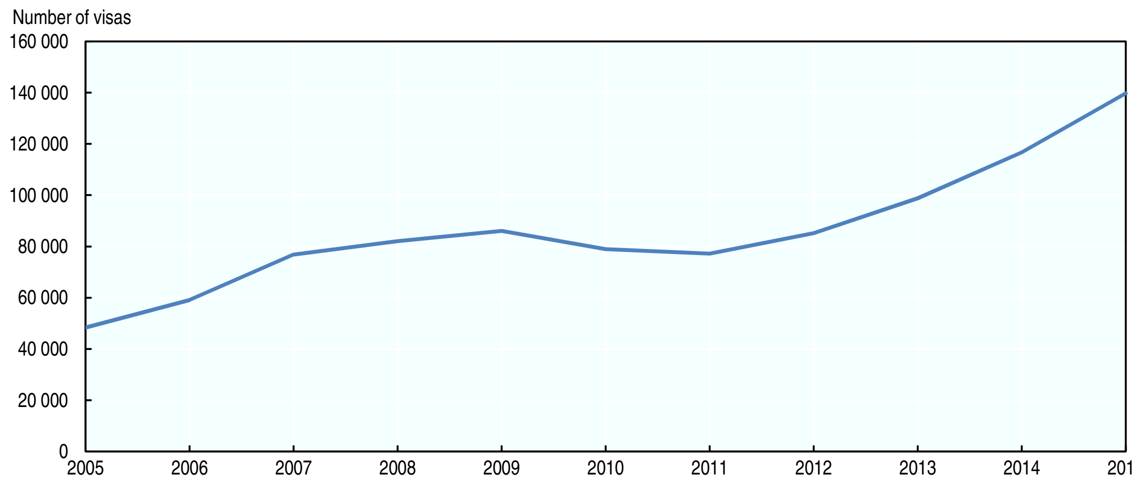
There is no yearly limit on the number of foreign workers who may be issued an H-2A visa, and their numbers have increased rapidly in the past five years, reaching 140 000 in 2015 (Figure 5.15). This figure represented 96% of positions requested, and 97% of complete applications were resolved in a timely fashion (more than 30 days before the date workers were needed).

Further proposed (but as yet not enacted) policies to grant legal status to significant numbers of currently unauthorised immigrants could increase their mobility in the US labour market, possibly encouraging unauthorised workers in agriculture to seek employment in other industries.

The Federal Government, through the US Department of Labor, also seeks to support farm workers and facilitate the operation of labour markets through the National Farmworker Jobs Program (NFJP), a nationally-directed, locally-administered programme for migrant and seasonal farm workers (MSFWs). The programme seeks to counter the chronic unemployment and underemployment experienced by MSFWs in the United States and Puerto Rico. It provides skills training, career counselling and assistance with job search. It also offers a range of support services designed to help farm workers and their families retain or stabilise their agricultural employment, or to participate in NFJP employment or training programmes, including direct assistance to help cover housing, transportation, nutrition, and child care costs.

In programme year 2012, more than 20 000 farm workers participated in NFJP; 86% entered employment, with a retention rate of 83% and average earnings over six months of USD 10 533.

Figure 5.15. H-2A Temporary visas certified for agricultural work, 2005-15



Source: US Department of Labor (2015), *Employment and Training Administration*, Office of Foreign Labor Certification. www.foreignlaborcert.doleta.gov/pdf/H-2A_Selected_Statistics_FY_2015_Q4.pdf.

StatLink http://dx.doi.org/10.1787/888933408675

Public support for research into labour saving mechanisation technologies

Mechanisation and the adoption of other labour-productivity-enhancing technologies has historically been the primary way in which agricultural employers have responded to rising labour costs. Public support of fruit and vegetable mechanisation reached its peak in the 1960s and 1970s, when hired farm labour costs were rising rapidly.

Agricultural engineers in university and government research institutions worked with growers and private machinery manufacturers to develop labour aids to increase worker productivity and mechanical harvesters to reduce labour requirements. Efforts to mechanise fruit and vegetable production stalled after 1980 because there was a large supply of labour available, which held down wages. In addition, the substantial, federal- and state-supported mechanical research system for fresh fruit and vegetables was mostly dismantled during the 1980s, leaving such research primarily to the private sector.

Now there is renewed interest in agricultural mechanisation associated with the loss, or potential loss, of unauthorised foreign workers. A recent ERS report, based on case studies of apples, oranges, strawberries, raisins, asparagus, and lettuce, found a range of potential adjustments in the face of rising costs and reduced availability of hired labour (Calvin and Martin, 2010). Some crops had already partially adopted mechanical harvesters, and adoption would likely spread. Some un-mechanised crops with substantial import competition would likely lose production and market share, while others would look to either mechanise or to introduce labour aids to improve worker efficiency.

The Food, Conservation, and Energy Act of 2008 created the USDA Specialty Crop Research Initiative (SCRI), providing USD 230 million for fiscal years 2009-12 to support research on five issues critical to the future of the US fruit and vegetable industry, including “improved mechanisation.” This is the first major federal investment in mechanisation research for fruit and vegetables since the early 1980s. Research funded under this initiative requires non-federal matching funds equal to the federal expenditure.

Regulating the terms and conditions of agricultural employment

There are a set of labour-market policies that are applied broadly across the economy; however, agriculture is exempt from some, and some types of farms are exempt from others, so these form an agriculture-specific policy.

For example, the Fair Labor Standards Act (FLSA) is the primary federal legislation governing minimum wage and overtime pay requirements in the US. Agricultural employers are exempt from the overtime requirement, and hence do not have to pay time-and-one-half wage rates for hours worked in excess of 40 per week. Most farm workers are covered by federal minimum wage provisions, except for those employed on smaller farms (defined with regard to the amount of labour utilised in the preceding calendar year)

Also exempt are agricultural employees who are immediate family members of their employer; those principally engaged on the range in the production of livestock; and local hand harvest labourers who commute daily from their permanent residence, are paid on a piece rate basis in traditionally piece-rated occupations, and were engaged in agriculture less than thirteen weeks during the preceding calendar year. Twenty nine states and the District of Columbia have set minimum wage requirements that are above the federal minimum, but many of these states also make exceptions for some agricultural workers.

Agriculture consistently ranks as one of the most hazardous occupations (Table 5.3). Occupational injury and fatality rates substantially exceed those found in construction, mining, and manufacturing as well as other major sectors of the economy. Fatality rates in logging exceed those in crop and animal production, which in turn are higher than in other sectors. Advocates argue that federal workplace safety protections are inadequate: A minority of States, including California and Washington, provide additional safeguards for farm workers. A small fraction of workers (about 2%) benefit from union collective bargaining agreements which require additional safety measures.

Table 5.3. Occupational injuries and fatalities, by industry, 2014

Selected US Industries	Injuries and illnesses per 100 workers	Fatalities per 100 000 FTE workers
All private industry	3.2	3.6
Crop production	5.5	22.2
Animal production	7.1	18.1
Forestry and logging	5.1	96.7
Mining	2.8	15.8
Construction	3.6	13.6
Manufacturing	4.0	2.2
Animal slaughter	7.6	3.8
Automobile manufacturing	7.1	1.3
Wholesale trade	2.9	4.8
Retail trade	3.6	1.8
Transportation	4.8	13.5
Professional and business services	1.2	2.6

FTE: Full-time equivalent.

Source: US Bureau of Labor Statistics (2015). www.bls.gov.

Workers' compensation benefits are secured by insurance policies, paid for by the employer. Each state has its own standards and rules. When a covered worker suffers a job-related injury or illness, he/she can receive medical benefits and/or a portion of her lost wages, if he/she files a workers' compensation claim and that claim is approved. However, many States do not require all farm employers to provide workers’ compensation insurance to migrant and seasonal farm workers.

Employers who hire legal temporary foreign workers under the H-2A visa programme are required to provide workers' compensation insurance or equivalent benefits to their employees. Thirteen states, the District of Columbia, Puerto Rico, and the Virgin Islands require employers to cover all seasonal agricultural workers to the same extent as all other workers. Thirteen additional states require large farmers to provide workmen’s compensation coverage for their migrant and seasonal farm workers. By contrast, sixteen states do not require employers to provide any coverage for migrant or seasonal farm workers.

Pesticides pose risks of short- and long- term illness to farm workers and their families. The exact number of workers injured each year by pesticides is unknown, because there is no national surveillance system for acute pesticide illness reporting and no surveillance system for tracking chronic illness related to pesticide exposure. Thirty states require health professionals to report suspected pesticide poisoning, but many incidents go unreported due to a number of factors, including workers’ failure to seek medical care, workers seeking medical care in Mexico, medical misdiagnosis, and health provider failure to report. Factors deterring farm workers and their families from seeking medical care for pesticide illness include lack of health insurance, language barriers, immigration status, cultural factors, lack of transportation, lack of awareness of or exclusion from workers’ compensation benefits, and fear of job loss.

Education and skills policy

Education policy affects innovation in at least three ways: a high level of general and scientific education facilitates acceptance of technological innovation by society at large; innovation systems require well-educated researchers, teachers, extension officers, and producers to develop relevant innovations; it is generally easier for farmers and business operators with higher education and skills to adopt some technological innovations. Continuous skills development (training, re-training) is essential to improve the matching of skills demand in an evolving agri-food sector, which needs to adopt productivity- and environmentally-enhancing technologies and practices.

Many studies investigated the link between education and technology adoption, which leads to productivity growth. Reviewing available literature, Huffman (2001) found that US farmers with higher levels of education appear to be more likely to adopt new and technologically sophisticated innovation. For example, they were more likely to adopt computer technologies, and to adopt certain new inputs in cattle feeding in the 1980s. More recently, Khanal, Gillespie and MacDonald (2010) found that dairy farmers with a college degree were more likely to adopt computerised feeding systems and new breeding technologies such as embryo transfer. Fernandez-Cornejo and McBride (2002) found that maize growers with a college degree were more likely to adopt genetically engineered insect-resistant or herbicide-tolerant seeds in the early years of commercial availability of such seeds. Schimmelpfennig and Ebel (2016) found that maize farmers with at least some college education are more likely to adopt precision agriculture technologies such as yield monitors, variable rate spraying, and automatic guidance systems.

Other studies estimated directly the link between education and total factor productivity (TFP). For example, in an analysis of a panel of US states covering 1950-1982, Huffman and Evenson (1993) found that the average years of education of the farm population had a large, positive, and statistically significant impact on state-level TFP. This study extends early work by Griliches (1963), who found that an index of the education of farm labour was positively associated with increased farm output, while controlling for other farm inputs in a model of agricultural production.[4]

Government plays a primary role in financing and managing education, both in general and specifically for agriculture, where the land-grant system of universities has played a major role in encouraging agricultural research, education, and extension.

State and local government have primary responsibility for administering and funding educational institutions. States set overall policies and standards for elementary and secondary institutions located; local governments administer public elementary and secondary schools; and local and state governments combine to provide most funding for public elementary and secondary schools. State governments also provide support for public post-secondary institutions, although the amount of support varies widely across states.

Overall achievement

The US education and training system is considered by the business community as one of the top five performers in the OECD area, together with Finland, the Netherlands and Switzerland (Figure 5.16). It is ranked particularly high for secondary and tertiary education enrolment rates (quantity of education, see details below). A large proportion of adults have reached tertiary education (44% compared to 33% on average across OECD countries) and the government aims to reach 60% by 2020 (OECD, 2015a). While the United States is not as highly considered for the quality of the education provided as measured by the ability to meet labour market needs, they still rank slightly above the OECD average and in recent years, unemployment rates have been below the OECD average for all levels of education.

Tertiary education offers a particularly high pay-off, and US workers with below secondary education face large earnings disadvantages throughout their working life (OECD, 2015a). The gender gap in favour of men is one of the largest in OECD countries in terms of earnings. Part of the difference can be explained by the lower share of women in high earning activities such as engineering and computer sciences.

In 2013, a lower percentage of students graduated from science and engineering programmes than on average across OECD countries (15% compared to 23% from tertiary programmes; 17% compared to 22% from Bachelor's programmes). Moreover, there has been a relative decline on doctoral graduates in science and engineering (OECD, 2014).

The United States is the global leader in tertiary education: it attracted alone close to one fifth of all foreign students in 2012, but they account for a small percentage of all students engaged in tertiary programmes.

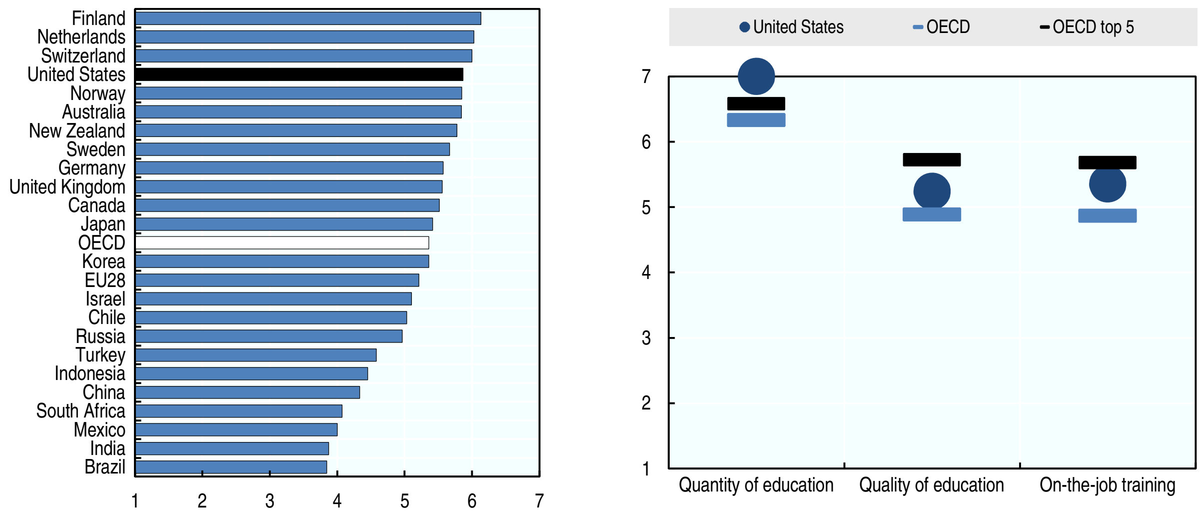
Despite the relatively high level of education, low "basic" skills are more common in the United States than on average across OECD countries. One in six adults has low literacy skills and nearly one in three has weak numeracy skills against an OECD average of one in five. In terms of "problem solving in technology-rich environments" the US results are a little worse than the OECD average. Explanations for the relatively weak performance of the United States include failings in initial schooling, lack of improvement in educational attainment over time, and poor skills in some subpopulations including migrants. Moreover, there are few signs of improvement as the average basic skills of young adults are not very different from older persons (OECD, 2013a and b).

Figure 5.16. Global Competitiveness Index: Higher Education and Training, 2015-16

Scale 1 to 7 (best)

A. Index of higher education and training, by country

B. US index of higher education and training by component



Indices for EU28 and OECD are the simple average of member-country indices.

Data for the Quantity of education index comes from UNESCO Institute for Statistics.

OECD top 5 refers to the average of the scores for the top 5 performers among OECD countries (Finland, Netherlands, Switzerland, Belgium and United States).

The quantity of education index is based on secondary and tertiary education enrolment rates from UNESCO Institute for Statistics. The quality of education index is based on responses from a WEF Executive Opinion Survey on "How well does the educational system meet the needs of a competitive economy; Executives' assessment of the quality of math and science education in schools and the quality of business schools; and on how widespread is Internet access in schools. The on-the-job-training index is based on survey responses on the availability of high-quality, specialised training services and the extent to which companies invest in training and employee development.

Source: World Economic Forum (2015), *The Global Competitiveness Report 2015-2016: Full data Edition*, Geneva 2015. www.weforum.org/reports/global-competitiveness-report-2015.

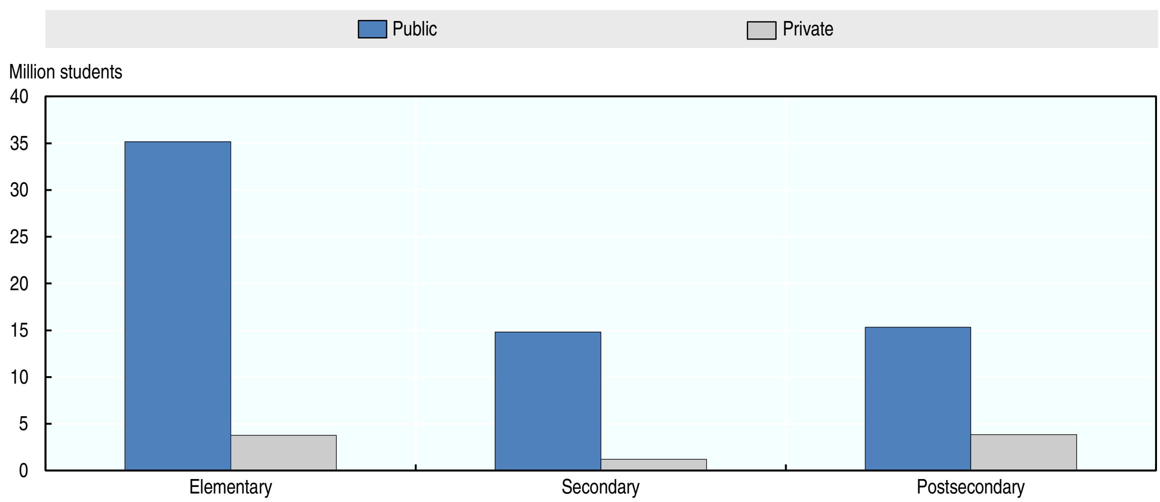
StatLink http://dx.doi.org/10.1787/888933408680

The performance of the initial schooling system is closely linked to adult skills and the US results from the international PISA assessment of the basic skills of 15-year-olds are consistent with the results for adults. According to the 2012 PISA survey, 15-year old US students perform below average in mathematics and the country ranks in the bottom half of OECD countries, and one in four does not reach proficiency levels, a higher percentage than the OECD average. Performance in reading and science are both close to the OECD average. As for adults, the socio-economic background has a significant impact on student performance in the United States. Although this impact has weakened over time, disadvantaged students show less engagement, drive, motivation and self-beliefs (OECD, 2015b, 2016).

General education enrolment, attainment and funding

Public schools account for 90% of enrolment in elementary schools, and 93% of enrolment in secondary schools (Figure 5.17). Religious schools account for about 80% of private elementary and secondary school enrolment, with the remainder enrolled in non-sectarian private schools. In turn, Catholic schools account for half of enrolment at religious schools. In addition, 1.77 million children between the ages of 5 and 17 are home-schooled (about 5% of total enrolment in elementary and secondary schools). State governments set educational standards (such as minimum days and hours in class; textbook coverage; diploma requirements) for all education in the state, and some provide financial support for non-public education.

Figure 5.17. Enrolment in US educational institutions by level and control of institution, 2014



Source: US Department of Education (2015), *National Center for Education Statistics*, http://nces.ed.gov/datatools/.

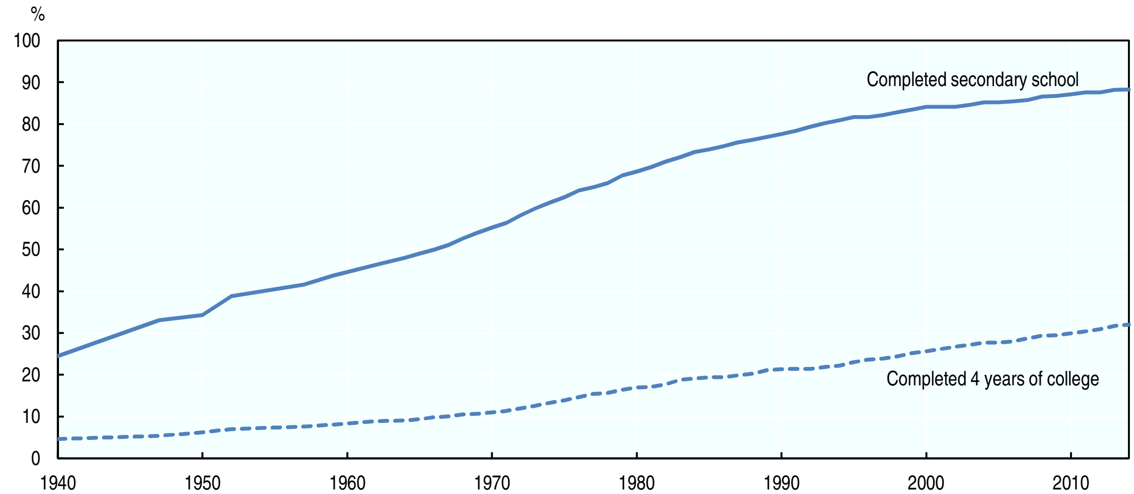
StatLink http://dx.doi.org/10.1787/888933408695

Postsecondary institutions include community colleges that provide associate degrees, usually requiring two years of full-time study; colleges and universities that provide bachelor degrees usually requiring four years of full-time study; and post-baccalaureate professional and graduate programmes usually located in universities. Private institutions account for about one-third of professional and graduate enrolments, one-fifth of enrolment in undergraduate four-year programmes; and less than one-tenth of enrolment in two-year associate degree programmes.

Increasing educational attainment has been one important force driving productivity growth in the US economy (Figure 5.18). By 2014, 88% of adults aged 25 and older had completed secondary education, as compared to 69% in 1980 and 25% in 1940; 32% had completed at least four years of college, compared to 17% in 1980 and 5% in 1940. However, there is concern that growth in educational attainment is slowing, and that slowing growth will constrain future economy-wide productivity growth.

Figure 5.18. Educational attainment in the United States, 1940-2013

Percentage of population, 25 or older



Source: US Census Bureau (2015), Current Population Survey. www.census.gov/programs-surveys/cps.html.

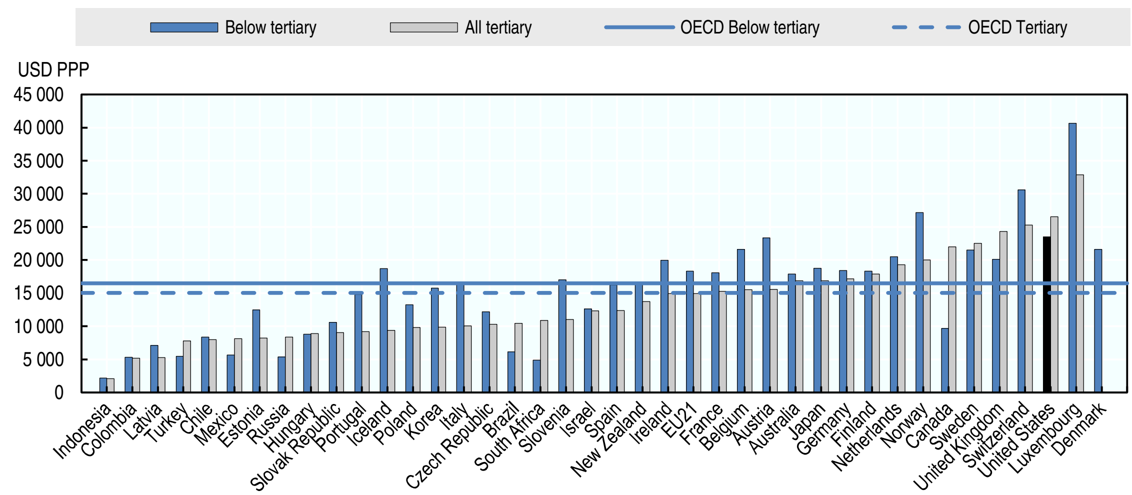
StatLink http://dx.doi.org/10.1787/888933408707

US expenditures on secondary education are equivalent to expenditures in other high-income OECD countries. Per-student expenditures for post-secondary education exceed expenditures in other OECD countries, and substantially exceed most (Figure 5.19). They remained higher despite a decrease between 2008 and 2012, in particular for tertiary education (OECD, 2015a). Public and private expenditure on education expenditure remained higher than the OECD average (Figure 5.20).

Parts of those expenditures are financed through tuition fees, and the United States has the highest average tuition fees for public universities among OECD countries. While US universities also offer relief from tuition in the form of grants, loans, and scholarships, there is concern that rising tuition is deterring attendance and slowing growth in educational attainment.

In a report considering economic policy reforms supporting growth, OECD (2015c) finds that a more inclusive education system would foster gains in productivity and income. The report welcomes the new law that bases interest rates for student loans on long-term treasury bonds, and efforts to increase access to pre-school education, as an effective means to reduce future inequalities. Recommendations include expanding effective pre-schooling initiatives, ensuring states meet quality standards to receive federal support, including for teachers, and supporting the introduction of common core standards in primary and secondary schools.

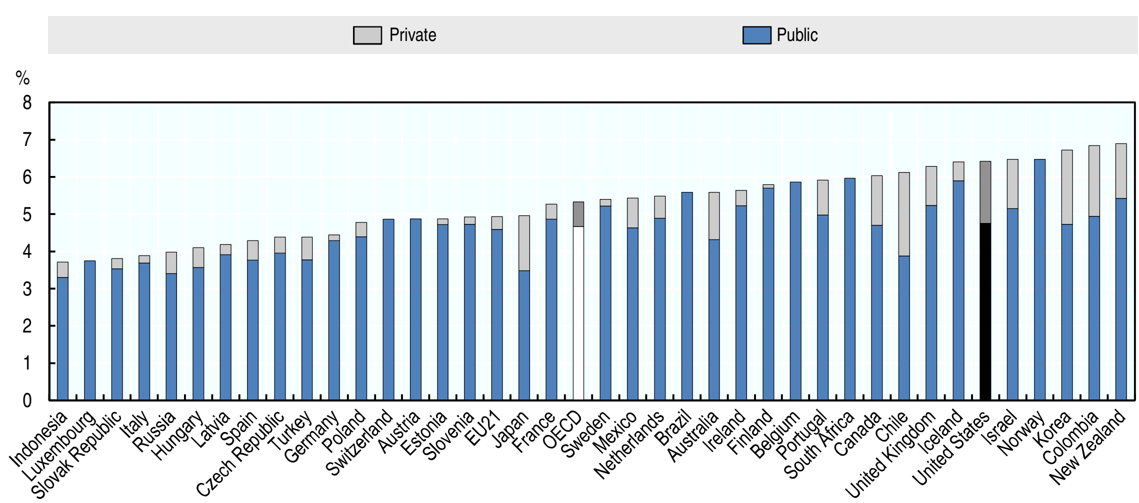
Figure 5.19. Average public expenditure per student by educational institutions, 2012



Source: OECD (2015a), *Education at a Glance 2015: OECD Indicators*, http://dx.doi.org/10.1787/eag-2015-en.

StatLink http://dx.doi.org/10.1787/888933408717

Figure 5.20. Public and private expenditure on educational institutions as a percentage of GDP, 2012



Public expenditure includes public subsidies to households attributable for educational institutions, and direct expenditure on educational institutions from international sources. Private expenditure is net of public subsidies attributable for educations institutions.

Source: OECD (2015a), *Education at a Glance 2015: OECD Indicators*, http://dx.doi.org/10.1787/eag-2015-en.

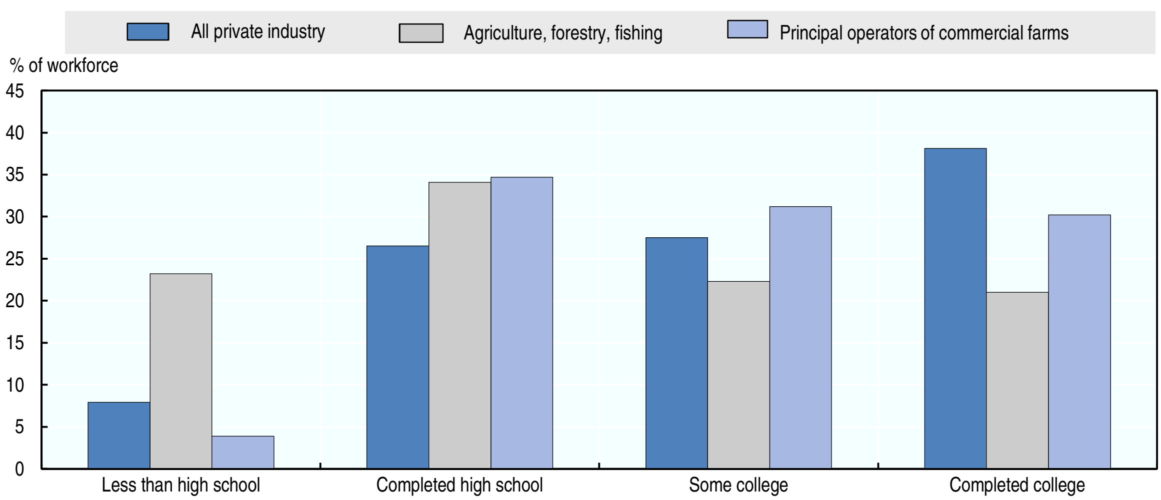
StatLink http://dx.doi.org/10.1787/888933408723

Agricultural education

About 38% of employees in private industry in the United States have completed a four-year college programme (including employees who have gone on to complete professional or graduate degrees). Another 28% have completed some college training, while only 8% have not completed high school (Figure 5.21). This distribution stands in sharp contrast to the workforce in agriculture: nearly a quarter of those employed in agriculture have not completed high school, while just over 20% have a four-year college degree. Labourers, typically with limited years in school, make up a substantial share of the hired workforce in agriculture, and greatly outnumber hired managers.

Farm operators fall in between (Figure 5.21). Thirty percent of the principal operators of commercial farms (farms with at least USD 350 000 in sales) have a college degree, while another 31% have completed some college, frequently in two-year programmes focused on agricultural specialties.

Figure 5.21. Educational attainment by industry of employment, 2014



Source: USDA (2015), *Agricultural Resource Management Survey for principal operators of commercial farms; 2014 Current Population Survey for others (25 years and older).* www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/arms-data.aspx.

StatLink http://dx.doi.org/10.1787/888933408732

The United States makes a significant investment in education for agriculture. The formal training of the next generation of farm operators begins in secondary schools where about 12 000 agricultural educators provide instruction in over 8 000 school-based programmes, to about 1 million students enrolled in food and agricultural education courses. Agricultural education in secondary schools combines classroom and laboratory instruction with experiential learning outside the classroom and leadership programmes delivered through organisations like 4-H and Future Farmers of America (FFA). Most formal food and agricultural education programmes are found in small towns and rural areas across the country. There are numerous and diverse programmes, but limited coordination in terms of design, implementation and monitoring (Mercier, 2015).

The United States has an extensive post-secondary programme of agricultural research and education, operated primarily through its system of land-grant institutions, a set of organisational innovations developed and extended in the 19th and 20th centuries. The Morrill Act of 1862 granted federally controlled land to the states for them to sell to raise funds to establish and endow colleges that would focus on the teaching of agriculture and the mechanical arts (though "without excluding classical studies"). A second Morrill Act, in 1890, aimed at the former Confederate states in the South. It provided cash instead of land, and required each state to show that race was not an admissions criterion, or to designate a separate land-grant institution for persons of colour.

In 1887, the Federal Hatch Act provided federal funding to establish a State Agricultural Experiment Station in each state for the purpose of agricultural research. Then, in 1914, Congress passed the Smith-Lever Act to create cooperative state extension services, intended to disseminate knowledge generated at colleges of agriculture to farms and consumers. The extension services are cooperative ventures of state and federal governments, and draw funding from each; county governments, through networks of county extension agents, are also cooperative extension partners.

The three legs of the institutional structure — research, education, and extension — were combined in colleges of agriculture in the land-grant institutions. The colleges of agriculture are augmented by colleges of veterinary medicine — 25 of the 27 in the country are located at land-grant universities. Some faculties at veterinary colleges have appointments in agricultural experiment stations, and veterinary colleges may also participate in cooperative extension programmes. Most states also established systems of public two-year community colleges and four-year state college systems; some of those colleges provide educational and extension programmes in agriculture and environmental and food sciences. While some will take jobs in farming, others will work in agricultural services, agri-food firms, government, and academia.

The land-grant universities and other institutions are expected to graduate an estimated 35 000 people annually between 2015 and 2020 with degrees in agriculture, renewable natural resources, or the environment. This number represents 61% of the projected 58 000 average annual openings for graduates with bachelor's or higher degrees in those areas. US universities award about 1 200 doctoral degrees in agricultural sciences each year, with a growing share being awarded in natural resources (including forestry, fisheries and wildlife) (Chapter 7). Scholarships for agriculture majors are sponsored by a variety of sources, including federal and state governments, professional associations, and colleges and universities.

Public extension programmes face increasing competition from private sector firms, as farmers obtain advice and technical guidance from independent crop consultants and custom service providers, veterinarians who also provide guidance on feed formulations and livestock marketing, technical specialists working for input suppliers, and lenders. Private sector advisors typically obtained their training at land-grant universities and associated institutions.

In addition to providing credit support (as described in Chapter 4), USDA also sponsors training programmes for new entrants into agriculture. The Beginning Farmer and Rancher Development Program (BFRDP), awards grants to organisations, including cooperative extension services, land-grant institutions, and others, who support beginning farmers and ranchers through workshops, educational teams, training, and technical assistance. Special emphasis is placed on women farmers, youth, veterans, current farm workers, and members of socially-disadvantaged and limited-resource communities, including international refugees.

More than 38 000 new and potential farmers participated in BFRDP project training events in programme year 2011. Of these 30% had little or no experience in agriculture, while less than one percent were current hired farm workers; 17% were women; and 16% were from socially disadvantaged groups. Forty-five percent of participants surveyed planned to start a farm after the training.

In the United States as in other countries, agricultural education systems face a number of challenges. Knowledge needed to improve agricultural productivity and sustainability include a broader range of topics, and a challenge is to move beyond production agriculture towards food and nutrition, natural resources and general knowledge such as ICT, business management and other socio-economic issues. There is a wide range of courses covering all these areas in the United States, but curricula are often highly specialised in science fields, in particular at tertiary level, and leave little flexibility to acquire additional knowledge that is increasingly important in research (e.g. ethics, economics) (Ciheam, 2015). Another challenge is to attract students in areas where jobs will be created. USDA projections indicate that there would be a 41% shortfall of US college graduates in food, renewable energy and environmental specialities compared to job openings over the period 2015-20 (Goecker et al., 2015). US higher agricultural education is extremely successful in attracting foreign students, which account for about 40% of doctoral degrees in agricultural sciences (Chapter 7). Finally, education is expected to contribute to improving understanding of agriculture and food in the general public (Mercier, 2015).

Summary

- Well-developed transport infrastructure facilitates the movement of agro-food products and farm inputs within the country and to points of export. Responsibilities for funding and operating infrastructure vary by means of transport. Most highway and waterway investment is publically funded, while freight railways are privately funded and maintained. Resources for road infrastructure originated mainly from a tax on gas, but are now more diversified. Train freight has become more concentrated and the issue of rail competition remains an important one for agricultural shippers, in particular when waterways are not an option.

- While access to infrastructure and services is unequal across regions (better in densely populated areas of the North-East), this is weighted against other considerations and does not prevent economic activity in areas with lower coverage.

- The quality of ICT infrastructure ranks slightly above the OECD average, but the number of mobile telephone subscriptions per capita is below average and fixed broadband access is unequal across the country. However, high speed Long-Term Evolution mobile telephony is particularly well-developed and covers over 95% of the continental territory. While Internet development has been mainly privately funded, recent federal programmes aim to enhance household Internet participation.

- Electricity transmission is organised into five networks which cannot be easily interconnected. Some deregulation of electricity generation and distribution started in the 1970s, but deregulation has slowed down as issues regarding competition emerged. Other changes include the diversification of energy supply away from coal as a fuel source towards natural gas (from fracking) and wind power. This diversification has benefited some farmers, which receive income from energy leases (natural gas, oil or wind). A number of large livestock farms also produce energy from anaerobic digesters.

- USDA is the lead federal agency for rural development programmes providing loans, grants and technical assistance to support development of rural companies, utility infrastructure and housing and community facilities. Over the years the share of assistance provided by USDA rural development programmes under grant and direct loan programmes has declined, while guaranteed loans have increased in importance. Other federal agencies such as the Department of Transportation or the Small Business Administration also provide assistance to rural communities. State and local governments also influence rural development through programmes, investments and tax incentives.

- The United States has one of most efficient labour market among G20 countries, and the least restrictive employment protection legislation, in particular for temporary forms of employment. Agriculture is exempted from some rules (overtime pay, minimum salaries in small farms, part-time farm household members, safety protection).

- The high US capacity to attract and retain talent is particularly important for agricultural innovation as the US innovation system attracts well-qualified nationals and foreigners.

- Agricultural employment has been steady for the last decade, and covers a diversity of full-time and part-time farm household members, as well as hired labour.

- Immigration policy matters for agriculture, which hires many farm workers born outside the country, in particular in the fruit and vegetable sector. New immigration laws, more vigorous enforcement of immigration laws, and changes in the incentives to migrate from Mexico have slowed immigration so that the hired farm workforce has become older and more settled. Specific visas are being issued to fill seasonal needs. A federal programme provides skills training, assistance to job search and other services to immigrant farm workers in order to reduce unemployment and stabilise their agricultural employment (with a good success rate as measured by the percentage of persons which have entered and kept employment).

- Labour saving mechanisation technologies provide a response to higher farm labour costs, and have contributed to TFP growth. In some sectors, they also have also permitted higher engagement of farm operators into off-farm activities. There is renewed interest for these technologies to respond to foreign labour shortage.

- The US education and training system is a top OECD performer for its high secondary and tertiary education enrolment rates, but less so for the ability to meet labour market needs, although unemployment levels are relatively low in the country. Tertiary education offers a particularly high pay-off.

- A lower percentage of students graduated from science and engineering programmes than on average across OECD countries. The gender gap in favour of men can be partly explained by the lower share of women in high earning activities such as engineering and computer sciences.

- The United States is a global leader in tertiary education, which attracts a high number of foreign students, including in agriculture.

- State and local governments have primary responsibility for administering and funding educational institutions with state governments setting educational standards. Most elementary and secondary schools are public, but private institutions account for about one third of professional and graduate enrolment. The US population reached high rates of enrolment and education attainment earlier than in other OECD countries, and the country spends more per student than most countries but the performance in terms of achievements and skills are below the OECD average.

- The United States makes a significant investment in education for agriculture. Agricultural education starts in secondary schools and combines classroom and laboratory instruction with experiential learning. An extensive post-secondary programme of agricultural research and education is operated primarily through its system of land-grant institutions, which combines research, education and extension activities.

- There are numerous programmes to provide education and training in agriculture and food-related areas, covering a large breadth of topics. Government support for training of entrants into agriculture focuses on women, youth, veterans, current farm workers and socially disadvantaged populations.

Notes

1. In each infrastructure component, the top five OECD countries are mostly smaller European countries with denser networks.
2. All years referred to in this chapter are fiscal years (FY).
3. Funding for these programmes is provided from electric cooperative investments and fees.
4. Griliches' findings influenced later work on the measurement of agricultural productivity; for example, the USDA productivity accounts include a quality-adjusted labour input, wherein hours of labour are adjusted for the education and experience profile of the farm labour force. The adjustment reflects the earnings advantages accruing to higher levels of education and experience in the US labour market.

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Chapter 6

UNITED STATES DOMESTIC AND TRADE-RELATED AGRICULTURAL POLICY

This chapter provides an overview of agricultural policies, focusing on commodity, crop insurance, conservation and energy programmes, and a brief discussion of agricultural-trade related measures. It also reports trends on the level and composition of support and discusses the likely impacts of agricultural policy measures on structural change, environmental performance and innovation in the sector.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Agricultural policy framework

Agricultural policy in the United States is generally governed by an omnibus legislative package familiarly known as the Farm Bill. The Farm Bill amends previous agricultural and related policies and establishes new policies on a five-year cycle, although that cycle can be extended or foreshortened depending on legislative priorities. The most recent Farm Bill, the Agricultural Act of 2014 (2014 Farm Bill), included 12 titles authorising policies and spending levels for programmes related to commodity support, conservation, trade, nutrition (domestic food assistance), agricultural credit, rural development, research and extension, energy, specialty crops, crop insurance, and miscellaneous administrative and specialised provisions.

This chapter focuses on programme changes under the commodity, crop insurance, conservation, and energy titles. It also includes a brief discussion of several programmes operated by US Department of Agriculture (USDA)'s Agricultural Marketing Service (AMS) that are governed by other legislation and provides details on trade- and energy-related measures, only some of which fall within the scope of the Farm Bill.

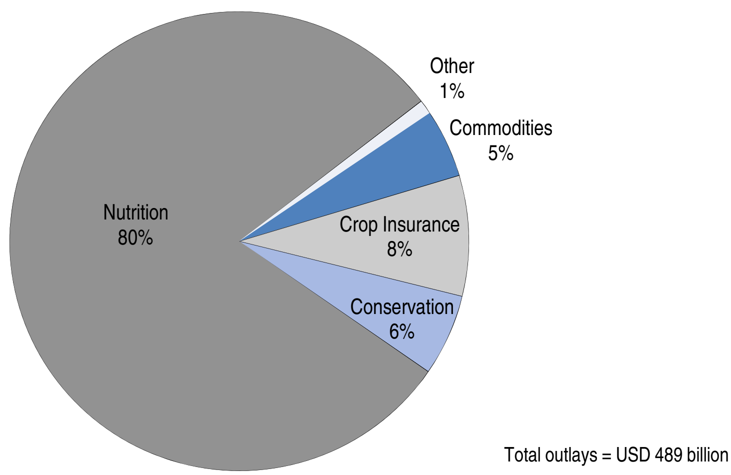
The 2014 Farm Bill made some significant policy changes to commodity support and crop insurance, conservation, and bioenergy programmes, while retaining and reorganising some longstanding programmes with minor adjustments. One significant change is the abolition of fixed direct income support based on historical production parameters. Another one is the cascade of choices given to producers under commodity support programmes, including crop insurance. Conservation programmes continued to provide a similar mix of programmes for addressing agri-environmental concerns, but policymakers reduced reliance on land retirement and reorganised programmes for conservation and environmentally enhancing practices on working lands into a smaller number of programmes linked by policy approach and regional priorities.

Farm Bill authorised programmes may be funded in two ways, either through mandatory funding or through appropriated funding. Mandatory (often termed "entitlement") programmes are funded for the life of the Farm Bill and provide programme payments to any recipients who meet eligibility requirements — eligible recipients are "entitled" to payments. Funds are provided through the Commodity Credit Corporation, a government-owned and operated corporation, and other mechanisms that provide for multi-year expenditures independent of annual Congressional appropriations. Discretionary programmes must be funded annually through the appropriations process; the Farm Bill authorises upper limits for these programmes, but annual appropriations may be lower or even zero.

Spending under the 2014 Farm Bill for mandatory programmes was projected at its passage to reach USD 489 billion over five years, 2014-18 (Figure 6.1). The largest share of projected outlays, 80%, will support nutrition programmes, providing vouchers to low-income households for retail food purchases and funding commodity purchases for use in the National School Lunch and other child and elderly feeding programmes. Commodity and crop insurance programmes make up 13% of projected outlays, and 6% of projected outlays support conservation programmes. The remaining 1% of projected outlays provides for mandatory programmes under all other titles. More recent projections that include actual expenditures for 2014 and 2015 raise the estimate for expenditures through 2018 slightly to USD 517 billion, but the shares of different programme types remain the same (US Congressional Budget Office, 2016a).

Outlays by the USDA, which implements most programmes authorised by the Farm Bill, provide a better indication of annual spending on programmes than the projections for mandatory programmes only (Figure 6.2). USDA outlays have increased 46% over the last decade, with the largest percentage increases in nutrition programmes and crop insurance. Nutrition programme increases, concentrated between 2008 and 2013, reflect the greater need and temporary programme expansions during the recent recession. The improving economy and expiration of programme expansions brought outlays down in 2014 from their 2013 peak. Crop insurance outlays also declined in 2014, as the weather events and crop prices behind their increase between 2008 and 2013 moderated. Commodity programme expenditures decreased over the decade, with most of that change as the result of the sustained rise in commodity prices that began in 2008. Conservation spending has remained steady at 5 to 6% of outlays over the decade. The share of funding provided to programmes authorised under other titles, most of which are subject to annual appropriations, has ranged from 7 to 14%.

Figure 6.1. Projected outlays under the 2014 Farm Bill, 2014-18

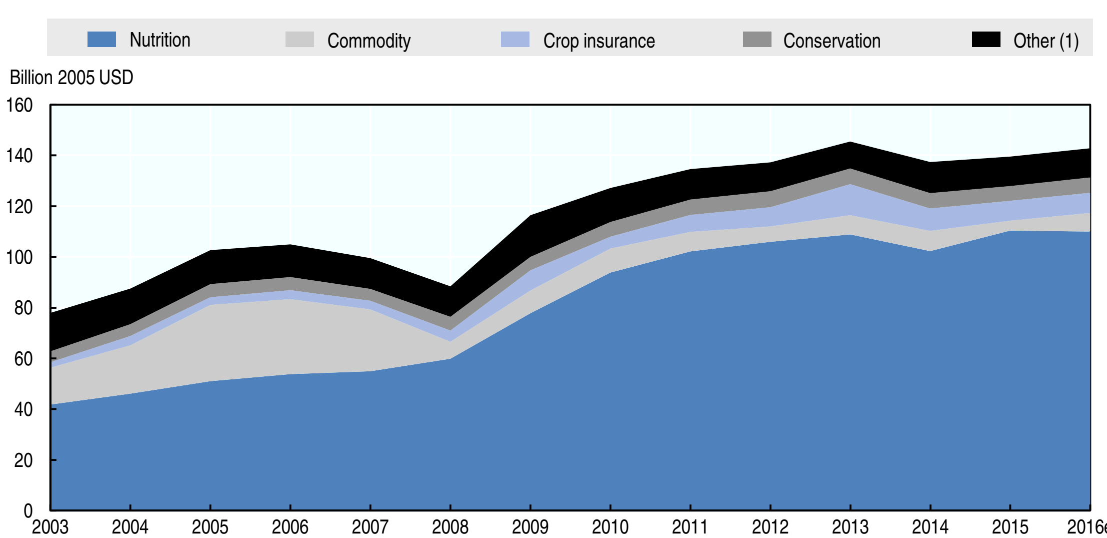


1. Includes foreign agriculture, credit, rural development, research and extension, food safety, and marketing and regulatory programmes.

Source: USDA Economic Research Service using data from US Congressional Budget Office (2014), Cost estimates for the Agricultural Act of 2014, January 2014. www.cbo.gov/sites/default/files/51317-2016-03-USDA.pdf.

StatLink http://dx.doi.org/10.1787/888933408745

Figure 6.2. USDA budget outlays, 2003-16



e: estimate. Does not include outlays for Forest Service or departmental administration.
1. Includes foreign agriculture, credit, rural development, research and extension, food safety, and marketing and regulatory programmes.

Source: Economic Research Service, using USDA (2015b), Office of Budget and Policy Analysis, Summary and Annual Performance Plans, 2005-2017. www.obpa.usda.gov/.

StatLink http://dx.doi.org/10.1787/888933408758

Broad-based domestic measures

Under the 2014 Farm Bill, titles with greatest direct impact on agricultural producers include Commodity, Crop Insurance, and Conservation. Some programmes under the Credit, Rural Development, Energy, and Research titles provide additional support, through farm ownership and operating loans, grants and loans to develop value-added agriculture and on-farm renewable energy systems, harvest and transportation assistance for bioenergy crops, research on animal health, pollinators, specialty crops, and organic agriculture, enhanced food assistance purchase programmes for fruits and vegetables, and assistance for local foods marketing.

Commodity programmes fall into three broad categories: market price support, direct income support, and risk management, although some programmes contain elements of more than one category. The 2014 Farm Bill made significant changes in the mix of programmes across these categories for both crops and livestock. These changes reflect developments in policymaker, stakeholder, and public views about the best means to achieve policy objectives. Increased choices for producers provide flexibility for producers to cover differing farm-level risks through different programmes. They are also expected to provide producers in different regions and of different commodities the flexibility to choose programmes best suited to their farm type and agronomic risks.

Commodity support programmes are almost exclusively offered at the federal level, although they are delivered through a system of State and county offices that serve as the local contact point for producers. States are essentially free to provide support to producers and the agriculture sector, but in general focus on technical assistance and education, research, marketing and promotion of State-produced products, and on conservation, farmland preservation, and other environmental programmes.

Market price support

Market price support, among the most distorting agricultural policy types, has become a progressively smaller share of US support to agriculture in recent decades. Market price support maintains the prices received by farmers in domestic markets through a combination of border measures and domestic supply controls. Consumers pay the higher market price, reducing the cost to government of providing commodity support. The 2014 Farm Bill repealed one of the two remaining market price support programmes, the Dairy Product Price Support Program, leaving the sugar programme as the only agricultural market price support programme operating in the United States. Legislative authority for the sugar programme requires USDA to operate the programme at no cost to the Federal Government to the maximum extent possible.

The sugar programme is designed to maintain market prices for sugar above a minimum level through the combination of a tariff rate quota (TRQ), marketing allotments, and a nonrecourse loan programme. The 2014 Farm Bill provides for USDA to make loans available to processors of domestically grown sugarcane and to domestic processors of sugar beets at loan-rate levels set in legislation for fiscal years 2014-18 (18.75 US cents per pound for raw cane sugar, 24.09 US cents per pound for refined beet sugar). Processors must agree to provide payments to producers that are proportional to the value of the loan received by the processor for sugar beets and sugarcane delivered by producers. USDA has the authority to establish minimum producer payment amounts.

Loans are taken for a maximum term of 9 months and must be liquidated along with interest charges by the end of the fiscal year in which the loan was made. When a loan matures, USDA must accept sugar pledged as collateral as payment in full, in lieu of cash repayment of the loan, at the discretion of the processor. Forfeited sugar can be offered to processors in exchange for reductions in production through reduced sugar crop planting. Forfeited sugar may also be sold for ethanol production (under the Feedstock Flexibility Program), or through buyback of TRQ import eligibility certificates.

To help avoid forfeitures, an Overall Allotment Quantity (OAQ) governs the amount of sugar that can be sold by processors in the United States for domestic human consumption. OAQs are set annually to at least 85% of estimated domestic consumption and adjusted throughout the marketing year to maintain sugar prices above the loan rate. OAQ allowances are then allocated to sugar processors, based on historical production. They are not tradable, but can be reallocated across regions. In recent years, US sugar production has frequently fallen below the OAQ allowance. Imports from Mexico, originally under duty-free/quota-free rules governed by the North American Free Trade Agreement and more recently under an agreement instituting an export limit, and from increased TRQs, have filled the gap to meet domestic demand.

Direct income support

Direct income support in the United States takes several forms, including both benefits based on output and payments based on historical production parameters. Rather than support producers by raising market prices, direct income support policies transfer the cost of support to government (taxpayers), allowing market prices to move freely.

Output-based benefits are provided through the Marketing Assistance Loan (MAL) programme, a low-interest post-harvest loan programme for producers of wheat, feed grains, cotton, rice, oilseeds, peanuts, wool, mohair, honey, and pulses. The MAL programme offers producers of those covered commodities the opportunity to borrow against harvested crops for up to nine months at below-market interest rates. Producers pay loans back in full with interest, or if market prices fall below loan rates, at the market price with interest forgiven, termed a marketing loan gain. Producers may also forfeit their commodity under loan in lieu of repayment. Producers may also choose to forgo taking out a loan and instead apply for a direct payment — loan deficiency payment — equivalent to the value of the marketing loan gain. For most commodities, loan rates have remained well below market prices in recent years.

Box 6.1. US commodity support policies 1996-2013

With the 1996 Farm Bill, the United States made a major change in its commodity policy programmes, decoupling producer support from current production. In place of the previous policy of deficiency payments tied to target prices and acreage controls, producers instead were offered a programme providing fixed payments based on historical acreage and yields (historical base) of programme crops. The 1996 Farm Bill also ended acreage controls, allowing producers to plant any commodity, with some exceptions for fruit and vegetable crops, on their historical base, or to idle that land, without affecting their programme payments.

Fixed decoupled payments continued until repealed by the 2014 Farm Bill. The Production Flexibility Contract (PFC) programme provided fixed payments determined by historical acreage and yields, or base, for wheat, feed grains, upland cotton, and rice until it was superseded in 2002 by the Direct Payment (DP) programme. The 2002 Farm Bill also allowed for readjusting base to more recent plantings and for adding historical base for oilseeds and peanuts. The 2002 Farm Bill ended the peanut price support programme based on peanut marketing quotas and it compensated quota holders through a three-year buyout programme. The tobacco marketing quota system was terminated in 2004 under separate legislation that provided tobacco quota holders with a quota buyout over ten-years.

From 1999-2001, ad hoc Market Loss Assistance (MLA) payments provided supplemental payments on historical base in response to a period of low commodity prices. The 2002 Farm Bill institutionalised these supplemental payments in the Counter-Cyclical Payment (CCP) programme, in which additional payments on historical base were triggered when commodity prices fell below legislated target prices.

Under the 2008 Farm Bill, a new revenue-based programme, the Average Crop Revenue Election (ACRE) programme, offered producers the option to tie commodity programme payments to revenue loss. Producers chose the ACRE programme as an alternative to participating in the CCP programme and also accepted a reduction in their fixed DPs and a lower marketing assistance loan rate. ACRE payments to producers were paid on the basis of a multi-level trigger design: first revenues for a commodity had to fall below a State-level revenue benchmark. If that occurred, participating farmers in that State could be eligible for a payment if their own farm revenues for that commodity fell below the revenue benchmark for their individual farm. Once enrolled, producers remained in the programme for the life of the 2008 Farm Bill. The programme's multiple trigger mechanism and the requirement that both landowners and operators agree to the choice, made the programme relatively complex and few producers chose to enrol in ACRE rather than remain in the CCP programme.

The 2008 Farm Bill also changed the dairy price support programme, replacing the longstanding milk support price with support prices for three dairy products — non-fat skim milk powder, butter, and cheddar cheese. A supplemental support programme, the Milk Income Loss Contract (MILC) programme, also provided direct payments to dairy producers when prices fell below a legislated target price. Payments were made on a limited level of production per farm to offset incentives for herd expansion. The 2014 Farm Bill repealed the Dairy Product Price Support Program and the MILC programme.

Loan rates remained unchanged under the 2014 Farm Bill, except for an adjustment in the upland cotton loan rate. Rather than a fixed loan rate as for other commodities covered by the loan programme, the upland cotton loan rate can vary within a range (USD 0.45-USD 0.52 cents per pound), following an average adjusted world price.

Direct income support based on historical production parameters, which began in 1996, saw significant changes under the 2014 Farm Bill, which repealed the Direct Payment (DP) and Counter-Cyclical Payment (CCP) programs, as well as the Average Crop Revenue Election (ACRE) programme.

New programmes tied to historical acreage and yields (historical base) include the Price Loss Coverage (PLC) and Agriculture Risk Coverage (ARC) programmes. Covered commodities under the new programmes include wheat, feed grains, rice, oilseeds, peanuts, and pulses. PLC provides direct payments to producers with historical base when the national average market price falls below the legislated reference price for the enrolled commodity. Much like the repealed CCP programme but with higher target reference prices, PLC provides a predictable level of price protection, although it is paid on a share of fixed historical base (85%), not on current production.

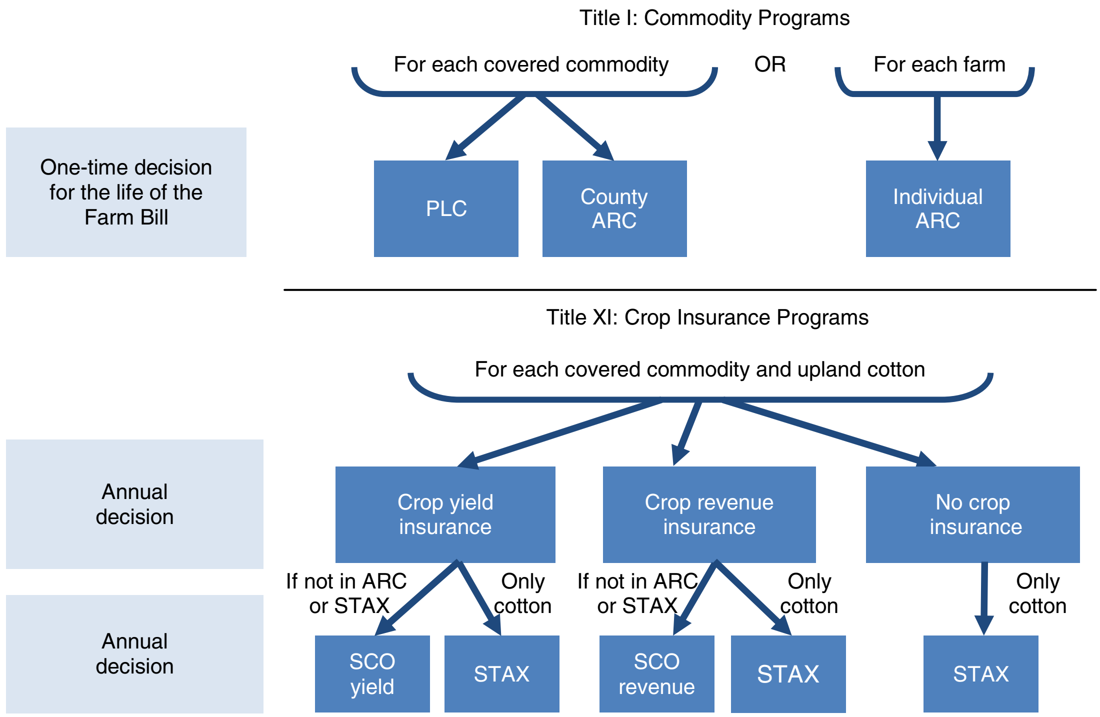
The ARC programme offers producers revenue, rather than price, protection, using a rolling average revenue guarantee based on national prices and either county yields (ARC-CO) or individual farm yields (ARC-IC). The ARC revenue guarantee offers producers some protection against multi-year yield and price volatility. As with PLC, the payments are made on a share of fixed historical base, not current production (85% for ARC-CO, 65% for ARC-IC).

Producers could choose either PLC or ARC-CO separately for each covered commodity on their farm. Alternatively, producers could choose ARC-IC, which then applied on a whole-farm basis to all covered commodities on the farm. Producers made these choices in 2014 to remain in place through 2018 without opportunity to make changes in the intervening years. As Figure 6.3 illustrates, producers faced a cascade of choices posed by the variety of commodity programme and crop insurance options offered in the 2014 Farm Bill. Producers holding historical base first faced the choice of whether to elect the PLC or ARC programs for each of their commodity bases. Those choices then affected annual choices they could make regarding purchase of crop insurance coverage. If they chose PLC for some of their historical base commodities, then they could purchase traditional crop yield or revenue insurance, as well as the new Supplemental Coverage Option (SCO) insurance that offered protection against small losses that would normally fall within the traditional crop insurance deductible. If they chose ARC, however, they would not be eligible for the SCO coverage, but could still choose traditional crop yield or revenue insurance coverage.

Upland cotton is not a covered commodity under the PLC and ARC programs. The Cotton Transition Payment (CTP) programme provided direct payments to holders of historical upland cotton base in 2014 and for some areas in 2015, until the new risk management programme for upland cotton, the Stacked Income Protection Plan (STAX), could be fully implemented. In addition, former upland cotton base became "generic" base under the PLC/ARC programme. Producers are not eligible for PLC or ARC payments on that base except in years when they plant it to a covered commodity.

Distinct differences by historical commodity base emerged in producer elections. For example, while producers elected ARC for 93% of maize and soybean base acres, producers elected ARC-CO for only 58% of wheat base and 33% of sorghum base. Conversely, producers elected PLC for 100% of long-grain rice and peanut base acres (USDA FSA, 2015). Choices were more mixed for other historical commodities. Only 1% of all participating farms elected ARC-IC, although farms electing ARC-IC accounted for 6 to 11% of pulse crop base acres.

Figure 6.3. 2014 Farm Bill offers producers both income support and risk management options



Source: USDA Economic Research Service.

Payments under the ARC and PLC programs have totalled USD 5.2 billion as of February 2016, with USD 4.4 billion in ARC payments and USD 0.8 billion in PLC payments (USDA FSA, 2016).

The move away from fixed direct payments on historical base towards programmes that make direct payments on historical base only when revenue or prices fall responded to the public debate that called for commodity programmes to provide support only in times of economic stress. In effect, the new programmes provide support during periods when it is most likely to be needed. The policy design that ties payments to historical base without production requirements does not allow producers to affect the level of their payments through planting decisions. As a result, these programmes avoid creating incentives for producers to make production choices to maximise programme payments.

Table 6.1. Producers' choice of programme, 2014-18

Percentage of base area covered by each programme

	PLC	ARC-CO	ARC-IC	
Barley	75%	22%	4%	100%
Canola	97%	2%	1%	100%
Maize	7%	93%	0%	100%
Crambe[1]	65%	34%	1%	100%
Dry peas	44%	50%	6%	100%
Flaxseed	63%	36%	1%	100%
Grain sorghum	66%	33%	0%	100%
Lentils	53%	41%	7%	100%
Large chickpeas	23%	66%	11%	100%
Long grain rice	100%	0%	0%	100%
Medium grain rice (southern)	96%	4%	0%	100%
Mustard	56%	38%	6%	100%
Oats	32%	67%	1%	100%
Peanuts	100%	0%	0%	100%
Rapeseed	44%	54%	2%	100%
Safflower	63%	34%	3%	100%
Sesame	84%	16%	0%	100%
Small chickpeas	23%	68%	9%	100%
Soybeans	3%	97%	0%	100%
Sunflowers	56%	43%	1%	100%
Temperate japonica rice	62%	34%	4%	100%
Wheat	42%	56%	2%	100%
US total	23%	76%	1%	100%

Farms elect ARC-CO and PLC on a commodity-by-commodity basis. A given farm may have elected PLC for some commodities and ARC-CO for other commodities. Thus, calculating percent of farms electing PLC or ARC-CO at the US level is not possible.

1. Crambe is an oilseed, which produces oil mostly for industrial uses.

Source: USDA (2016b), Farm Service Agency, ARC/PLC Program, ARC/PLC Election Data (www.fsa.usda.gov/programs-and-services/arcplc_program/).

Risk management

US farm policy has become increasingly oriented to risk management, even as more traditional programmes continue. US producers use a combination of strategies and tools to manage risk, most of which are not government-based. Among private risk management tools, producers have access to futures and options contracts for major commodities offered on commodity exchanges, as well as opportunities for forward contracting for delivery of grain through local elevators and processors. Among producers of maize, soybeans, and wheat who use contracting in their operations, around 30% participate in hedging their risks through futures contracts and 15% do so through options. These tools are more limited for minor crops and to some extent for livestock. However, some of those producers can also use production contracts or marketing contracts with downstream firms as a risk management strategy. More than 40% of US production is under some form of production or marketing contract (MacDonald and Korb, 2011).

Many producers also use on-farm storage or marketing through cooperatives to manage price risk by delaying sales in expectation of higher prices. Producers may also diversify their operations between livestock and crops, for example, to balance risk. Incomes from different crops and from livestock generally do not follow the same cycles, allowing low income from one to be offset by higher income from the other. Double cropping and diversification across different crops and types of livestock may accomplish similar results. Credit can also provide a strategy for managing risk, and US farm households also often manage risk through off-farm income sources, including off-farm jobs, farm-related and non-farm businesses, investment income, and social insurance transfers (e.g. social security).

The ARC programme offers producers an option to link their historically based income support to a rolling-average revenue guarantee as an alternative to a fixed reference price. The 2014 Farm Bill also increased the risk management options available to producers through insurance programmes, which are available for purchase annually. The Supplemental Coverage Option (SCO) offers policies in conjunction with traditional crop insurance policies for commodities that producers have elected to enrol in PLC. Producers cannot purchase SCO policies for commodities they have elected to enrol in ARC. Producers typically purchase crop insurance policies to cover around 70-75% of yield or revenue; SCO policies provide an option for additional area-based coverage between the underlying insurance policy and 86% of yield or revenue. SCO policies will cover either yield or revenue risk to match the underlying crop insurance policy. Because SCO covers the most active layer of losses, it can have a higher premium rate than many traditional insurance policies for the same coverage level, but also has a higher premium subsidy rate (65%) than most traditional crop insurance policies. SCO policies have not been a popular option with producers.

Producers of upland cotton may purchase SCO coverage but are alternatively eligible for the STAX programme. STAX is an upland cotton-only revenue insurance option similar to SCO in that coverage is based on county revenue averages. It does not require purchase of an underlying traditional policy, although it offers protection only for losses between 10 and 30%. Premium subsidies are higher for STAX (80%) than for SCO. Like SCO, few producers have shown interest in purchasing these policies.

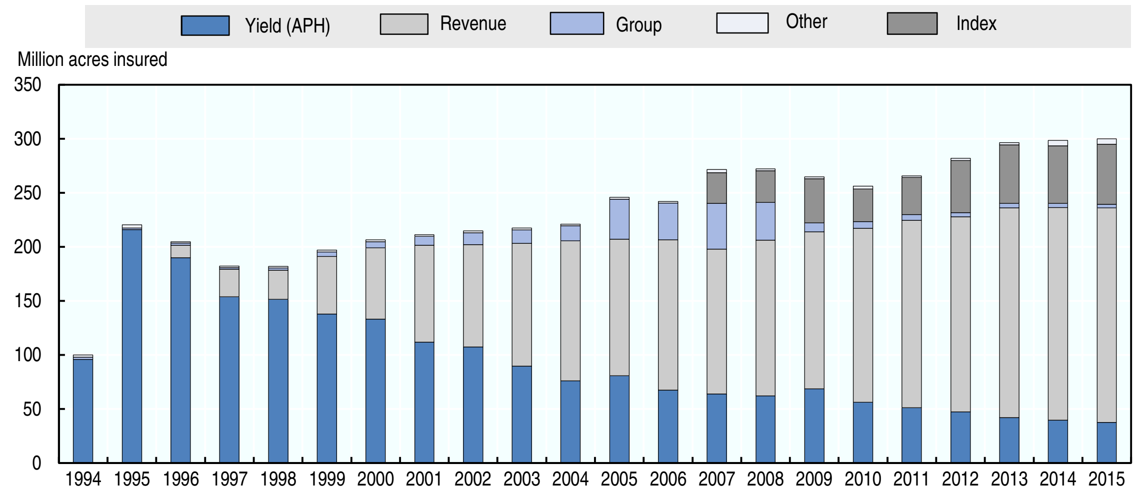
Traditional crop insurance, which provides the bulk of federal crop insurance coverage, is purchased through private insurance companies at a subsidised rate (on average, producers pay only about 40% of their premiums). USDA's Risk Management Agency (RMA) subsidises the insurance premiums as well as a portion of the companies' administrative and operating expenses and shares underwriting gains and losses with the companies under the Standard Reinsurance Agreement. Insurance policies make indemnity payments to producers based on current losses related to either lower than expected yields (crop yield insurance) or lower than expected revenue (revenue insurance). Farmers purchase insurance before planting, but usually pay premiums near harvest.

Crop insurance options have offered expanding risk management choices over time (Figure 6.4). Producers may choose from among a variety of yield and revenue insurance products, although not all policy types are available for all crops in all areas. The increasing availability of revenue insurance products has steadily expanded their share of all crop insurance policies; by 2015, more than 75% of all crop insurance policies were revenue products. Revenue products lower insurance costs when natural (price-yield) hedge reduces revenue variability.

Actual Production History (APH) yield protection is the oldest and most widely available crop insurance product. It protects farmers against yield losses due to natural causes such as drought, excessive moisture, hail, wind, frost, insects, and disease. Yield coverage levels are based on a producer's expected yield, which is calculated from the farm's actual production history (average yields over the last four to ten years). The farmer can select a coverage level from 50 to 75% of average yield (up to 85% in some areas), and a guarantee price, ranging from 60 to 100% of the crop price established annually by RMA.

Catastrophic Risk Protection Endorsement (CAT) coverage provides a lower level of coverage on yield losses at a low cost to producers. It pays indemnities at a rate of 55% of the established price of the commodity when farm yield losses are more than 50%. Producers pay an administrative fee for each crop insured. Coverage above the CAT level is often referred to as “buy-up” coverage.

Figure 6.4. Crop insurance coverage, by option, 1994-2015



APH: Actual Production History (farm or sub-farm unit level).
Revenue: APH yield x national price (farm or sub-farm unit level).
Group: County yield (GRP) or country revenue (GRIP).
Index: Rainfall or Vegetation (pasture, rangeland and forage).

Source: USDA (2015c), *Economic Research Service compilation of Risk Management Agency data*, www.rma.usda.gov/.

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Dollar Plan coverage pays for both quantity and quality yield losses and is limited to some high-value crops (e.g. fresh market tomatoes and strawberries). It guarantees a dollar amount per acre rather than a particular yield level. Index insurance, which offers area coverage based on estimated production losses related to indexed levels of vegetation or rainfall, is available for the Pasture, Rangeland, and Forage pilot programme and the Apiculture pilot programme.

Area Risk Protection Insurance (ARPI) policies may cover either yield or revenue and use county yields as the basis for determining a yield loss or calculating revenue coverage levels and actual revenue loss (similar to the SCO and STAX programs). When the county yield for the insured crop falls below the trigger level chosen by the farmer, an indemnity is paid. Yield coverage is available for up to 90% of the expected county yield; producers may select revenue coverage levels from 70 to 90% of expected county revenue. ARPI premiums are usually lower than those for individual insurance.

Revenue Protection (RP) provides protection against a farmer’s gross revenue for an individual crop falling below a guaranteed level. Farmers elect a coverage level (50-85%), which is multiplied by their APH yield and the higher of 1) the base market price, which is an average of the harvest-time futures price for a month prior to planting; or 2) the month-long harvest market price for the last month of the contract to determine the revenue guarantee.

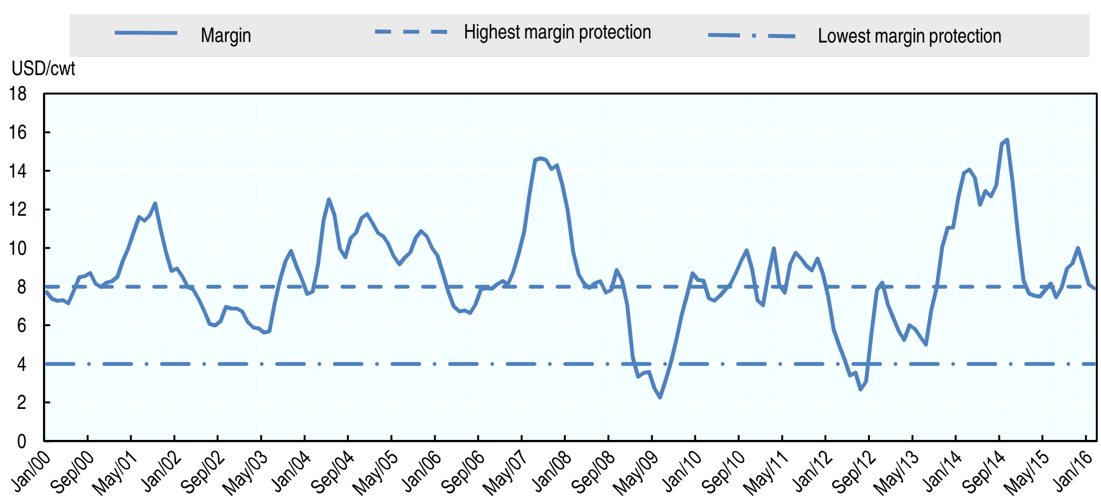
Whole Farm Revenue Protection, established in 2015 from the previous Adjusted Gross Revenue (AGR) pilot programs, insures the revenue of the entire farm rather than an individual crop by guaranteeing a percentage of average gross farm revenue, a share of which may come from livestock revenue. The plan uses information from a producer's farm business income tax forms to calculate the policy revenue guarantee.

Crop insurance is widely available, but coverage is not available for all crops in all areas. Crops for which insurance products are not available, generally specialty crops, previously could secure only catastrophic coverage for yield losses (50% loss at 55% of average market price) under the Noninsured Crop Disaster Assistance Program (NAP). The 2014 Farm Bill provided for an expansion of NAP that allows producers to buy additional yield loss coverage for some or all of their eligible commodities (up to 65% of losses at 100% of average market price).

The new Margin Protection Program (MPP-Dairy) for dairy provides a risk management alternative to former price support and income stabilisation programmes. Dairy producers can purchase coverage under MPP-Dairy to insure their operations at a selected level of average national dairy production margin (the difference between the US all-milk price and average feed cost). On enrolment, operations register their recent production history as the basis for coverage, then choose annually the share (25-90%) of that historical production (adjusted annually for national average milk production increases) to cover and at what margin level (USD 4.00-USD 8.00 per hundredweight (cwt) of milk). Coverage at the lowest margin level (USD 4.00) is available for a USD 100 annual administrative fee; coverage at higher levels requires a premium in addition to the administrative fee. Premiums range depending on the margin level selected and the amount of production covered (premiums are higher for production above 4 million pounds annually).

This programme provides payments to producers when the difference between milk prices and feed prices falls below USD 4.00-USD 8.00, depending on chosen coverage level. Since 2000 milk margins have been more often above the upper protected margin than below, and have fallen below the minimum protection margin only twice (Figure 6.5). In 2015, payments triggered for only a few months at the USD 8.00 margin level, totalling payments of only about USD 700 000.

Figure 6.5. Historical dairy margins in relation to MPP bounds, 2000-16



Source: USDA (2016c), Farm Service Agency. www.fsa.usda.gov/.

StatLink http://dx.doi.org/10.1787/888933408772

The 2014 Farm Bill permanently authorised four of the five standing disaster assistance programmes under the previous Farm Bill that help livestock producers and orchard, vineyard, and nursery tree growers manage the risk of loss from natural disasters — the Livestock Indemnity Program (LIP), Livestock Forage Program (LFP), Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish Program (ELAP) — and the Tree Assistance Program (TAP). The reinstated programmes included provisions for retroactive coverage to 1 October 2011, when the programmes had expired. The 2014 Farm Bill did not re-authorise the expired whole-farm revenue-based crop disaster assistance programme, Supplemental Revenue Assurance (SURE).

LFP provides compensation to eligible livestock producers who have suffered grazing losses due to drought or fire on land that is native or improved pastureland with permanent vegetative cover or that is planted specifically for grazing. LIP provides benefits to livestock producers for livestock deaths in excess of normal mortality caused by adverse weather or by attacks by animals reintroduced into the wild by the federal government. ELAP provides emergency assistance to eligible producers of livestock, honeybees and farm-raised fish for losses due to disease and costs incurred for some disease prevention, adverse weather, or other conditions, such as blizzards and wildfires, not covered by LFP and LIP. TAP provides financial assistance to qualifying orchardists and nursery tree growers to replant or rehabilitate eligible trees, bushes, and vines damaged by natural disasters

Market-related support

Several other programmes provide indirect market-related support to producers through government purchases or government oversight of marketing programmes. These include both emergency, short-term demand-enhancing programmes and industry-requested programmes to stabilise marketing of specialty commodities. The Dairy Product Donation Program (DPDP) requires the Secretary of Agriculture to purchase dairy products for donation to low-income groups when dairy margins, as determined under the MPP-Dairy, fall below USD 4.00 per cwt the two preceding months. The programme remains in effect until specified margin or product price levels are met or until purchases have been made for three consecutive months. Dairy products will be purchased at prevailing market prices in consultation with public and private non-profit organisations serving the nutrition needs of low-income populations, which will distribute the donations through food banks and other feeding programmes. The DPDP programme has never been triggered.

USDA’s Agricultural Marketing Service (AMS) administers the programme "Funds for Strengthening Markets, Income and Supply", which is authorised under Section 32 of the Agricultural Adjustment Act of 1935, as amended. Section 32 authority provides funding both for cash child nutrition subsidies and the acquisition of perishable food commodities for distribution to child nutrition programmes, a small share of which are made as emergency surplus removals for disaster relief and short-term market stabilisation. Purchases are made at current market prices through a transparent bid process.

The Agricultural Marketing Agreement Act of 1937 authorised federal milk marketing orders, which have been modified many times since then. A classified pricing system and revenue pooling are two key elements of milk marketing orders. Milk marketing orders set minimum prices paid by milk processors for milk used for fluid beverage purposes and manufactured dairy products. These minimum milk prices are set by formulas and change each month with changes in prices of major dairy products. They are not set to provide price support, but rather to improve availability of fluid milk for consumers in deficit production regions. Minimum prices of milk used for fluid beverage purposes differ according to a geographic price structure. While most US milk is marketed through federal milk marketing orders, some milk is marketed through similar State programmes, and some is marketed outside both federal and state programmes.

More than 20 fruit and vegetable commodities are covered by marketing orders administered by the USDA's Agricultural Marketing Service (AMS). Marketing orders are operated at the request of the industries, which agree voluntarily to federal oversight of certain aspects of their operations. Once established, marketing orders become binding on all individuals or businesses handling the commodity in a geographic area covered by the order, including importers, who must comply with grade, size, quality, and/or maturity regulations under the order. Marketing orders enforce product quality standards, regulate the flow of product to markets, standardise packages and containers, create reserve pools for storable commodities, and authorise production and marketing research and advertising. About one-third of fruit and vegetable marketing orders (ten) have authority to control volume, but that authority has been rarely used in recent years (see section on regulations in Chapter 4).

Domestic measures targeting specific issues

Agri-environmental programmes

Agri-environmental programmes, generally governed by the Conservation Title of the Farm Bill, have multiple objectives. Originally focused primarily on soil quality and water quality and conservation, these objectives have expanded to include wildlife habitat, air quality, carbon sequestration, energy conservation, and preserving farm and ranch lands. At the same time, programmes have become increasingly focused on working lands and away from land retirement, although targeted land retirement remains an important programme component.

While most of these conservation issues occur in some form across the United States, specific problems are often regionally concentrated. For example, water quality and conservation are a critical focus in California, while in the Northern Great Plains wetlands and grassland preservation rank high among environmental concerns. Soil erosion problems, the historical core of USDA conservation programmes, differ regionally as well, with wind the primary concern across the Great Plains and other open lands with little forest cover, and water the greater concern in hilly or mountainous topographies. The Secretary of Agriculture has designated eight critical conservation areas for concentrated attention under the 2014 Farm Bill's Regional Conservation Partnership Program:

- Chesapeake Bay Watershed — water quality, agricultural soil erosion and nutrient runoff;
- Great Lakes Region — water quality, agricultural soil erosion and nutrient runoff;
- Mississippi River Basin — water quality, agricultural soil erosion and nutrient runoff;
- Colorado River Basin — water conservation and sustainable use of water resources;
- Longleaf Pine Range — long-term sustainability of pine forest ecosystems;
- Columbia River Basin — water quality and quantity for salmon habitat;
- Prairie Grasslands Region — flood mitigation, irrigation efficiency and water conservation, wildlife habitat conservation;
- California Bay Delta — water quality and conservation, wildlife habitat conservation.

Conservation programmes in the United States are operated at the federal, state, and local levels. Federal programmes are operated by USDA through the Farm Service Agency and the Natural Resources Conservation Service. At the state and local level, a system of field offices and local conservation districts interacts directly with producers to implement federal programmes, which may be supplemented by additional funds from the State and county and from local conservation districts. Conservation districts are special districts authorised by the States to organise producer cooperation with federal agricultural conservation programmes. They are generally contiguous with counties, but in some cases may be at a sub-county scale.

Many states and some counties also operate agricultural conservation programmes that are independent of federal programmes. These may address more local conservation issues or may reflect heightened public concerns in some States about broader environmental problems. For example, California operates a greenhouse gas cap-and-trade programme that recently linked with a similar programme operated by the Canadian Province of Québec; both New York and Massachusetts offer assistance for production of renewable energy from agricultural sources using anaerobic digester technologies; and a large number of States and some counties operate farmland preservation programmes.

At the federal level, the United States operates two types of agri-environmental programmes — mandatory conservation compliance for participants in most farm programmes, and voluntary conservation programmes that may involve land rental, cost-share for implementation of conservation practices, and incentive payments. Producers may receive technical assistance to implement both types of programmes.

Mandatory conservation compliance requires that producers apply a soil conservation system on highly erodible cropland and refrain from draining wetlands in order to benefit from other farm programmes, including both income support and risk management and insurance programmes. For example, under Highly Erodible Land Conservation (HELC) provisions — often referred to as "sodbuster" provisions — farmers who crop highly erodible land must apply an approved soil conservation system or risk becoming ineligible for nearly all agriculture-related farm programme benefits, including farm commodity programmes, crop insurance premium subsidies, conservation programmes, disaster assistance, farm loan programmes, and other benefits. Under Wetland Conservation provisions (often referred to as "swampbuster"), producers must refrain from draining wetlands or face the loss of farm programme benefits. Cross compliance requirements have been in place since 1985, but the 2014 Farm Bill reinstated the requirements for producers receiving crop insurance premium subsidies, which were in place from 1985-96.

Voluntary conservation programmes include both land retirement and programmes on working farmland, including agricultural land preservation and adoption of environmentally friendly production practices. The 2014 Farm Bill consolidated voluntary conservation programmes into a smaller number, but most previous options remain in place. Federal conservation spending includes financial assistance to farmers as well as spending on services provided by federal agencies.

Five programmes presented in Box 6.2 account for more than 95% of spending on voluntary programmes that provide financial assistance to farmers in exchange for either retiring land from crop production or adopting more environmentally benign practices on land that is in production. In 2015, the five programmes received budget authority amounting to USD 1.81 billion for the CRP (or 37.5% of total funding for these programmes), USD 1.35 billion (28%) for the EQIP, USD 1.18 billion (24.4%) for the CSP, USD 394 million (8.2%) for the ACEP; and USD 93 million (1.9%) for the RCPP.

Box 6.2. Conservation programmes in the 2014 Farm Bill

Land retirement programmes

The Conservation Reserve Program (CRP) generally provides 10-15 year contracts to remove land from agricultural production and place it in grass or tree cover. A large majority of CRP contracts enrolled whole fields or whole farms. Increasingly, however, CRP contracts fund high-priority, partial-field practices such as filter strips and grass waterways, rather than whole-field or whole-farm enrolments. Up to 2 million acres of grassland can also be enrolled in CRP if landowners agree to keep the land in grazing use. CRP enrolees receive land rental payments, and additional payments reflecting a share of the costs of installing various conserving practices on their land.

The Agricultural Conservation Easement Program (ACEP) provides long term or permanent easements for preservation of wetlands and the protection of agricultural land (cropland, grazing land, etc.) from commercial or residential development. It includes the former Wetland Reserve Program and the Farm and Ranchland Preservation Program. The Grassland Reserve Program was split between the CRP and ACEP.

Working land programmes

The Environmental Quality Incentives Program (EQIP) provides financial assistance to farmers who adopt or install conservation practices on land in agricultural production. Common practices include nutrient management, conservation tillage, field-edge filter strips, and livestock exclusion from streams. Sixty percent of programme funds are targeted to livestock related practices and at least 5% are targeted to wildlife-related practices.

The Conservation Stewardship Program (CSP) supports ongoing and new conservation efforts for producers who meet stewardship requirements on working agricultural and forest lands. CSP provides two types of payments through five-year contracts: annual payments for installing new conservation activities and maintaining existing practices; and supplemental payments for adopting a resource-conserving crop rotation.

The new Regional Conservation Partnership Program (RCPP) is designed to coordinate conservation programme assistance with partners to solve problems on a regional or watershed scale. Financial assistance is coordinated through RCPP but provided to producers largely through "covered" programmes: EQIP, CSP, ACEP, and Healthy Forests Reserve Program. Up to 7% of the dollars or acres available under each of these programmes will be allocated through RCPP.

Conservation Technical Assistance (CTA), also a voluntary programme, provides ongoing technical assistance to agricultural producers who seek to improve the environmental performance of their farms. The assistance is provided through a system of professional conservationists based in most US counties to help farmers and other landowners manage natural resources on their land. Conservationists provide individual on-farm review of conservation problems, helping producers develop conservation plans that incorporate practices and technologies to meet required standards under cross-compliance and other federal, state, and local environmental regulations. CTA also provides area-wide, community, and watershed plans in cooperation with local leadership to identify resource conservation priorities and methods and funding sources for addressing those needs. Spending on CTA has remained between USD 700 and USD 800 million per year over the last ten years (USDA, 2016a).

Producers can also receive technical assistance to prepare the specialised conservation plans required for financial assistance under voluntary USDA conservation programmes to implement environmentally friendly practices.

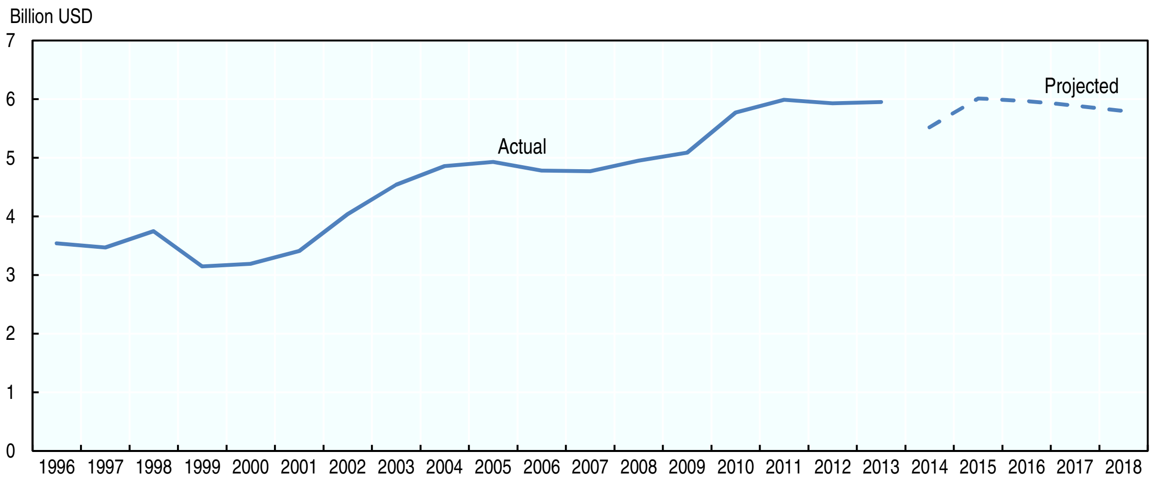
Conservation Innovation Grants (CIG), a sub-programme of EQIP, encourages innovative approaches and knowledge and technology transfer for conservation on agricultural land. CIG leverages federal funding by partnering with other public and private entities through a competitive grants programme. Funding is targeted to small projects that demonstrate opportunities for application of proven and emerging technologies for a wide range of users through on-the-ground pilot projects, field demonstrations, and on-farm conservation research. CIG provides 50% of project costs, which must be matched by funds from other sources secured by the grant recipients. The programme is funded at USD 20 million annually (accounting for 0.35% of all conservation spending) and has distributed USD 234 million in grants since it began in 2004. CIGs have supported very specific innovations, most of which have been only recently introduced.

USDA undertakes research on the economic productivity and environmental impacts of various pest management and nutrient strategies. In certain circumstances, farmers can improve on-farm productivity and financial performance through practices that also reduce the use of agricultural chemicals, and USDA education and technical assistance programmes support those actions. However, education alone is unlikely to be sufficient to incentivise practices to protect environmental quality, because most environmental benefits occur off the farm.

Conservation programme spending overall has seen substantial increases since 1985, when the Conservation Reserve Program (CRP) was first introduced (Figure 6.6). After more than a decade of rapid growth, projections based on the 2014 Farm Bill indicate a levelling off in funding for conservation programmes (Figure 6.7). Between 2014 and 2018, the Congressional Budget office (CBO) estimates mandatory conservation spending of USD 28 billion, about USD 200 million less than CBO's projection of 2014-18 spending if the programmes and provisions of the 2008 Farm Bill had been extended.

Programmes on working farmland have increased markedly since 2002. Under the 2014 Farm Bill, this transition will continue (Figure 6.8). The CRP will be reduced from its previous cap of 32 million acres to the new maximum limit of 24 million acres in 2017, and combined funding for EQIP and CSP is projected to rise above 50% of conservation spending for 2014-18. EQIP, CSP, and their predecessor programmes accounted for only 11% of funding in 1996-2002, 32% in 2003-2007, and just over 40% in 2008-13 (Claassen, 2014) (Figure 6.9).

Figure 6.6. Annual spending on major USDA conservation programmes, 1996-2018

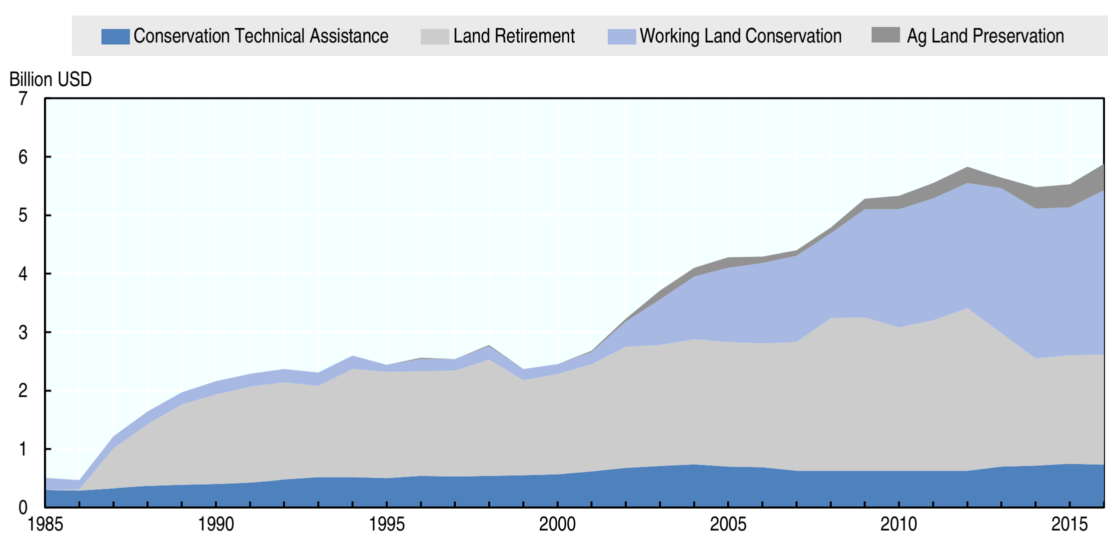


Includes the Conservation Reserve Program (CRP),·the Agricultural Conservation Easement Program (ACEP), the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), the Regional Conservation Partnership Program (RCPP), the Conservation Technical Assistance (CTA) and predecessor programmes. Spending is adjusted to constant (2012) USD, assuming annual inflation of 2% for 2014-18. CTA funding is assumed flat for 2014-2018 at USD 714 million (nominal).

Sources: USDA Economic Research Service analysis of USDA (2015b), Office of Budget and Policy Analysis (OBPA) data on actual funding for 1996-2013; OBPA projections for 2014, Congressional Budget office projections for 2015-18 for CRP and CSP, and funding specified in the 2014 Farm Act for 2015-18 for ACEP, EQIP, and RCPP. www.cbo.gov/sites/default/files/51317-2016-03-USDA.pdf.

StatLink http://dx.doi.org/10.1787/888933408788

Figure 6.7. Evolution of conservation spending, 1980-2016

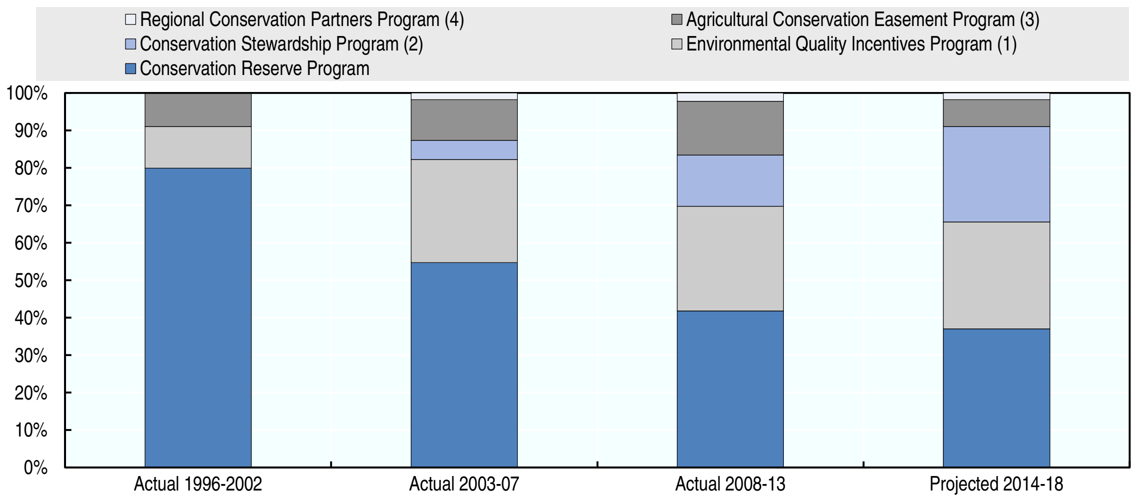


The years 2015 and 2016 data reflect 2014 Farm Bill programs; 2015 budget authority estimated; 2016 budget authority proposed.

Source: USDA (2015b), Office of Budget and Policy Analysis, Summary and Annual Performance Plans, 2005-2017; and Congressional Budget Office.

StatLink http://dx.doi.org/10.1787/888933408790

Figure 6.8. Conservation programmes in the 2014 Farm Bill



1. Includes EQIP and the Wildlife Habitat Incentive Program (WHIP) for 1996-2013.

2. Includes the Conservation Security Program for 2002-07.

3. Includes the Wetland Reserve Program, Farmland Protection Program, and Grassland Reserve Program (easement portion) for 1996-2013.

4. Includes the Agricultural Water Enhancement Program, Chesapeake Bay Watershed Program, Cooperative Conservation Partnership Initiative, and Great Lakes Basin Program for 1996-2013.

Source: USDA, Economic Research Service, using data from Congressional Budget Office (2014), *Cost Estimates for the Agricultural Act of 2014*, www.cbo.gov/sites/default/files/51317-2016-03-USDA.pdf.

StatLink http://dx.doi.org/10.1787/888933408805

Conservation programme spending has also become increasingly targeted to land where retirement or enhanced practices can have the greatest environmental benefit. Whole-field and whole-farm CRP expenditures, for example, are awarded on the basis of expected environmental benefits and increasingly CRP funds have been reoriented to support high-value partial field land retirements that provide riparian buffers, field-edge filter strips, wetland restoration, and wildlife habitat. While most conservation programme spending is mandatory, it is subject to budget or area caps. As a result, enrolment is competitive — for some programmes, fewer than 50% of prospective participants are accepted.

Competition for participation is generally managed through a bidding process. In most cases, eligible producers submit offers for participation, specifying the practices they are interested in applying and details of the land to which they would apply them, as well as, in some cases, what payment they are willing to accept. These offers are scored on potential environmental benefits and ranked according to the value of benefits against the cost of payments producers are willing to accept to achieve them. The primary ranking mechanism is the Environmental Benefits Index, which scores bids on the practices offered and the payments required to reach a composite score that can rank all bids on a single scale (Box 6.3).

Box 6.3. The Environmental Benefits Index

The Environmental Benefits Index (EBI) is a ranking system used by USDA's Farm Service Agency (FSA) for enrolling land in the Conservation Reserve Program (CRP). The CRP offers long-term rental payments, and technical and cost-share assistance for establishing conserving practices (generally cover plantings) to control soil erosion and improve water quality and wildlife habitat on environmentally sensitive farmland. The EBI is a mechanism for determining which contract offers from agricultural landowners provide the greatest environmental benefits at the least cost, in order to assure that programme funds are used most effectively. FSA assesses data on 5 environmental factors plus cost to competitively rank CRP contract offers:

- Wildlife habitat benefits that will result from the cover plantings offered;
- Water quality benefits from reduced erosion, runoff, and leaching;
- On-farm benefits from reduced erosion;
- Benefits that are likely to endure beyond the contract;
- Air quality benefits from reduced wind erosion; and
- Cost (rental rate offered)

Each contract offer is scored according to the benefits provided in each of these categories, which can be affected by both planned practices and by the location and environmental sensitivity of the land offered. All offers in the same signup period are comparatively ranked and selections for CRP contracts are made based on this ranking.

Adaptation to climate change

At the federal level, efforts to prepare for adaptation to climate change started with the launch of the Interagency Climate Change Adaptation Task Force in 2009 to provide "federal support and coordination for adaptation planning at federal, state, local, and tribal levels of government". Each federal agency was required to develop a specific plan addressing the challenge of climate change adaptation in the frame of its goals and activities.

The USDA Climate Change Adaptation Plan provides "a vulnerability assessment, reviews the elements of USDA's mission that are at risk from climate change, and provides actions and steps being taken to build resilience to climate change." (USDA, 2014b) The USDA released a study reviewing climate change impacts on agriculture, and analysing adaptation and policy responses in this area (Walthall et al., 2013). It also launched seven Regional Climate Hubs, and included inputs from each USDA sub-agency into the USDA Plan.

The Regional Climate Hubs are expected to help farmers in their choices for adapting to climate change. They have three main purposes: 1) provide farmers with technical assistance for climate change, based on the most updated scientific knowledge on the subject; 2) regularly assess the risks and vulnerabilities associated with climate change for regional agriculture, and disseminate information useful to farmers' choices in this regard; and 3) raise awareness and educate farmers on issues of climate change adaptation. For these missions, Regional Climate Hubs may work with other federal agencies, as well as universities.

USDA also aims at developing capacity building in the area of climate change in all sub-agencies. A USDA Global Change Task Force that includes representatives from each agency of the USDA concerned by climate change meets monthly to set the course and coordination of adaptation activities related to climate change.

Bioenergy policies

Bioenergy policies form a component of the US government's overall energy strategy, which aims to support economic growth, improve energy security by reducing net oil imports, and address the challenges of climate change (US Council of Economic Advisors, 2015). The strategy also includes the application of new energy efficiency standards in transportation and in certain energy-using products; support for alternative energy sources such as wind and solar power through tax incentives, direct support, and mandates; support for improvements in energy infrastructure for better alignment with emerging energy sources; and support for research on energy. Energy sector innovations — particularly the development of new technologies for mining natural gas and oil as well as improvements in solar and wind technologies — and bioenergy policy initiatives have combined to lead to a substantial shift away from coal as a source for electricity generation and toward natural gas and renewables (Figure 5.8), and to sharp reductions in net oil imports (Council of Economic Advisors, 2015).

The Renewable Fuel Standard (RFS), which sets annual mandates for blending biofuels with gasoline for transportation fuel use, functions as the primary policy supporting biofuels use and development in the United States. The RFS was first enacted in the Energy Policy Act of 2005 and was revised under the Energy Independence and Security Act of 2007 (EISA). The EISA also set new standards for average fuel economy in motor vehicles; set new energy efficiency standards for ten major household appliances and light bulbs; provided new initiatives aimed at reducing energy use in federal buildings; and provided support for R&D. The EISA aims to create incentives for research spending, innovation, and technology adoption through the imposition of product standards.

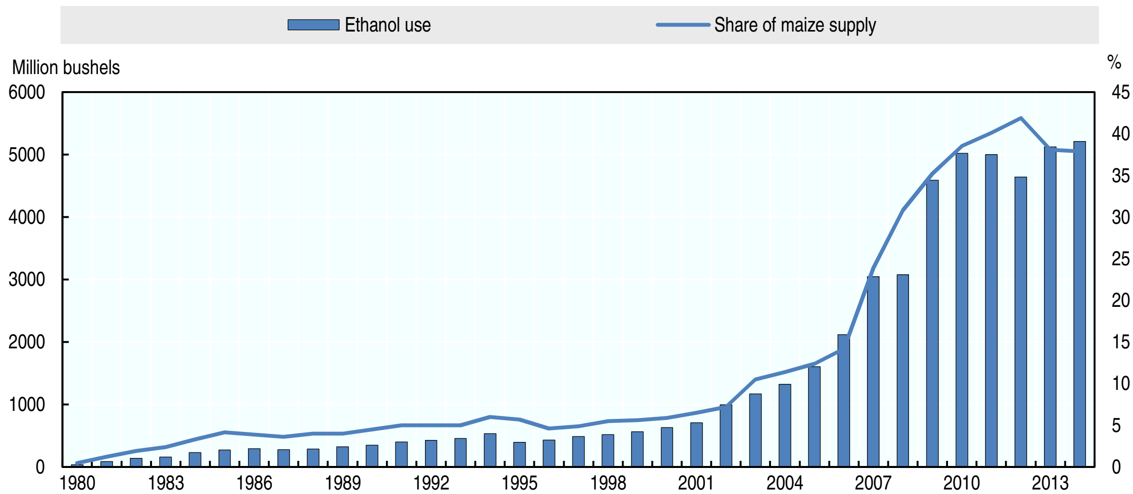
The 2007 EISA RFS established a progressively growing mandate for the use of renewable biofuels in the United States, from 9 billion gallons in 2008 to 36 billion in 2022, drawing on four nested categories of biofuels, based on their greenhouse gas (GHG) reduction rating (relative to a 2005 baseline of 100% gasoline or 100% diesel) and feedstock: conventional renewable fuel, advanced biofuel, biomass-based diesel, and cellulosic biofuel. The advanced category includes biomass-based diesel, cellulosic, and other advanced biofuels. Feedstocks for other advanced biofuels include sugarcane and biogas from waste materials; for biomass-based diesel, they include oil crops, animal fats, recycled cooking oil, and non-food grade maize oil (a by-product of the dry mill ethanol production process). Cellulosic ethanol feedstocks include agricultural and forestry residues, dedicated energy crops (e.g. switchgrass, miscanthus), and urban waste (e.g. food waste and municipal solid waste). (Bracmort, 2016; Duffield et al., 2015).

The RFS established a complex nested structure among the four biofuel categories. Ethanol from maize starch and grain sorghum qualifies as conventional renewable fuel, with a minimum GHG reduction of 20%.[1] While the 9 billion gallon RFS for 2008 could be met entirely from conventional renewable fuels, their use was capped at 15 billion gallons in 2015, and later increases in the RFS were to be met primarily from advanced biofuels (with a minimum GHG reduction of 50%), which were to provide at least 21 billion gallons by 2022. Of that total, 1.28 gallons must be from biomass-based diesel fuels[2] and 16 billion gallons must be from cellulosic biofuels (which must meet a GHG reduction requirement of 60%).

To date, conventional renewable fuel in the form of maize-based ethanol has made up around 98% of blended biofuels, which has had an impact on maize production in the United States. Maize used for ethanol more than tripled over 2005-13, with an annual growth rate of nearly 24% per year from 2005-11 and reaching a peak of 43% of production in 2012 (a drought year with unusually low maize production). Maize production has also risen over that period, posting record highs in 2004, 2007, 2009, and 2013. At the same time, use of distillers dried grains (DDGs), a co-product of the ethanol dry-milling process, has increased as a partial off-set to maize use in feed for dairy and beef cattle.

Most vehicles in the United States run on a mixture of gasoline with 10% ethanol (E10), as infrastructure, liability, and automotive design constraints limit the use of higher ethanol blends. Practically, this practice links ethanol use to total US gasoline consumption, which has declined since 2008, in part due to the effects of the recession but in part due to policies regarding fuel efficiency standards. Because of this "blend wall" imposed by total gasoline consumption, and the RFS cap on conventional biofuels, the share of maize used for ethanol fell to 37% by 2015, and is projected to fall to 34% by 2025 (Westcott and Hansen, 2016). In contrast, while biodiesel use lags behind maize-based ethanol in the United States, production increased between 2005 and 2015 from 90 million to 1.27 billion gallons and makes up about 25% of soybean oil use.

Figure 6.9. Share of maize used for ethanol, 1980-2014



Source: USDA (2015a), Economic Research Service, Feed Grains database. www.ers.usda.gov/data-products/feed-grains-database.aspx.

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The EISA, and other statutes supporting bioenergy, was intended to encourage greater research investments on bioenergy projects, and to lead to expanded innovation. Globally, public R&D expenditures in support of bioenergy rose from around USD 200 million in 2000 to USD 600 million in 2007; global expenditures fell in the wake of the 2008-09 economic crisis, but US expenditures were increased again as part of fiscal stimulus initiatives in 2009-10 (Fuglie et al., 2011). Private firms also expanded their research on biofuels, and in 2009 global private biofuels R&D expenditures were estimated at USD 1.47 billion (Fuglie et al., 2011).

However, the EISA also set an aggressive mandate for the growing use of cellulosic biofuels, but the necessary developments in infrastructure, processing, and efficient feedstock production have not been forthcoming, despite significant investments in research. As a result, the US Environmental Protection Agency (EPA), which develops the specific rules to implement the RFS, has waived all or part of the cellulosic component of the RFS in each year. The agency has not adjusted the overall annual target for renewable fuel use, thereby effectively increasing the mandate for other advanced biofuels, primarily sugarcane ethanol and biodiesel (Tyner, 2013).

The RFS is enforced by creating blending obligations for each type of biofuel, based on refiners' and importers' fuel volumes. For example, a refiner with a volume of 1 billion gallons of gasoline would have to provide the EPA with certificates showing that it blended 100 million gallons of ethanol (10%) in its production. These certificates are called Renewable Identification Numbers (RINs), and they are transferable among firms— if firms use more renewable fuels than required, they can sell their surplus RINs to other blenders. The EISA also provides for a RIN credit trading system that allows some flexibility for shifting obligations across years. The transferable RIN market allows for increased efficiency in meeting the RFS, and positive RIN prices for various biofuel categories indicate that the RFS is binding, and is driving marketplace behaviour.

Certain other federal ethanol support policies, including tax credits and import tariffs, were ended or allowed to expire in 2012. Ethanol remains competitive as an octane enhancer, however, which likely will keep ethanol production at or above RFS mandate levels even without those additional supports (Irwin and Good, 2015). Additional support beyond the RFS continues for biodiesel production through a USD 1.00 per gallon tax credit for blenders of biodiesel fuel.

The 2014 Farm Bill also provides authority for additional bioenergy programmes, primarily through providing incentives for research, development and adoption of renewable energy, including solar, wind, and anaerobic digesters, as well as cellulosic ethanol, and soy-based biodiesel (Schnepf, 2014). Programmes provide assistance for research and development of advanced biofuel feedstocks, conversion of energy systems to use alternative feedstocks, and assistance to producers to establish and maintain production of non-commodity biomass feedstocks and biobased products. USDA has implemented these provisions through a number of separate programmes.

The Biomass Crop Assistance Program (BCAP) provides financial assistance to producers to produce and deliver non-commodity biomass feedstocks for qualified biomass conversion facilities that use biomass feedstocks to produce heat, power, biobased products or advance biofuels. Assistance may be provided as matching payments for delivery of eligible material by producers to conversion facilities or as establishment and annual payments for some producers who contract to produce eligible biomass crops in specific BCAP project areas.

The Rural Energy for America Program (REAP), administered by USDA's Rural Business and Cooperatives Service, provides grants and loan guarantees to agricultural producers and small businesses to purchase or install renewable energy systems or to make energy efficiency improvements. To be eligible for assistance, agricultural producers must earn at least 50% of their gross income from agricultural operations and small businesses must be in rural areas. The funds may be used for a variety of renewable energy systems, including biomass, geothermal, small-scale hydropower, hydrogen, solar, and ocean tidal, current, or thermal energy, and for increasing the efficiency of existing energy systems.

The Feedstock Flexibility Program for Bioenergy Producers encourages the domestic production of biofuels from surplus sugar. Bioenergy producers may purchase surplus sugar from the Commodity Credit Corporation during years when USDA has determined that CCC sugar purchases are required to avoid forfeiture of sugar held as loan collateral under the sugar nonrecourse loan programme.

The Biomass Research and Development Initiative funds research and development and demonstration projects in the areas of feedstocks development, including feedstocks logistics systems; biofuels and biobased products development; and biofuels development analysis focused on life-cycle environmental, social, and economic impacts of projects. Universities and other higher education institutions, national laboratories and other federal and state research agencies, non-profit organisations, and small businesses may be funded for 80% of research and development costs or 50% of demonstration project costs. The initiative is jointly administered by the Department of Energy and USDA. Funding for the research programme was significantly reduced from a high of USD 40 million in mandated funds annually to USD 3 million under the 2014 Farm Bill.

The Biofuels Infrastructure Partnership awards competitive grants, matched by States, to expand the infrastructure for distribution of higher fuel blends of ethanol. Commodity Credit Corporation funds must be used to pay a portion of the costs related to the installation of fuel pumps and related infrastructure dedicated to the distribution of higher ethanol blends, for example E15 and E85, at vehicle fuelling locations. The matching contributions may be used for these items or for related costs such as additional infrastructure to support pumps, marketing, education, data collection programme evaluation and administrative costs.

The Advanced Biofuel Payments Program provides quarterly payments to advanced biofuel producers based on the quantity produced in the quarter. Annual payments for increases in advanced biofuel production over the previous year are also available.

The Biobased Markets Program, also known as the Biopreferred Program, is intended to assist in developing and expanding markets for biobased products. The programme includes mandatory biobased supplies and services procurement requirements for federal agencies and federal contractors and a voluntary product certification and labelling programme. The "USDA Certified Biobased Product" label verifies the product meets the required standard for renewable biological ingredients.

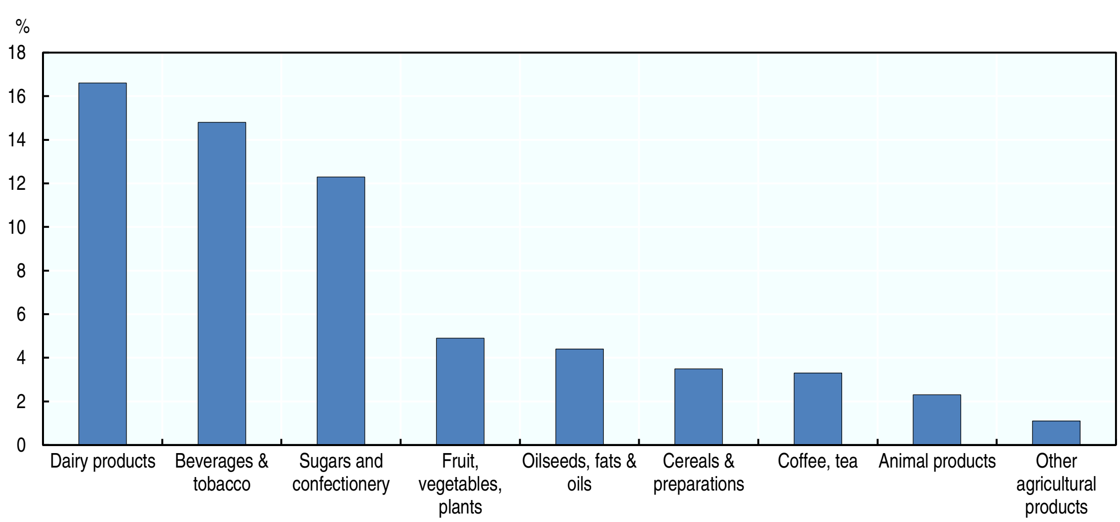
The Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program offers loan guarantees for the development, construction, and retrofitting of new and emerging technologies for the development of advanced biofuels, renewable chemicals, and biobased products manufacturing facilities. Loans are available through USDA's Rural Business and Cooperatives Service for up to USD 250 million (but not more than 80% of eligible project costs) for the development, construction, and retrofitting of new and emerging technologies for biorefineries and biobased manufacturing facilities. Biorefinery facilities may also be eligible for funds under the Repowering Assistance Program, which offers grants to biorefinery facilities for up to half the costs of installing renewable biomass systems for heating and powering their facilities, or for producing new energy from renewable biomass.

Trade-related measures

US tariffs are relatively low by international standards, in particular for capital goods (Figure 6.11). Agricultural tariffs are slightly above the average for non-agricultural products, but the majority are quite low (Figures 6.10 and 6.11). Applied tariffs[3] averaged 5.1% for agricultural products and 3.5% for non-agricultural products in 2014 (WTO, 2015). For agricultural products, 77.2% of tariff lines have applied tariffs less than or equal to 5%. However, tariffs in certain agricultural commodities are higher than the national average, most notably dairy products (17.2%), sugar and confectionery products (11.7%), and beverages and tobacco (18.6%).

The United States employs many simple tariffs, but there are some agricultural sectors for which it employs a tariff rate quota (TRQ). These two-tiered tariffs apply one rate to a certain amount of the imported good, and a considerably higher tariff on any further imports in excess of the initial quota. If the out-of-quota tariff rate is high enough, this has the effect of behaving as a quota or quantity limit on imports. There are tariff rate quotas on certain dairy products, certain meats, sugar and sweeteners, cotton, tobacco, animal feed, and certain fruits (US Customs and Border Protection, 2015)

Figure 6.10. US tariffs on agricultural commodities, 2015



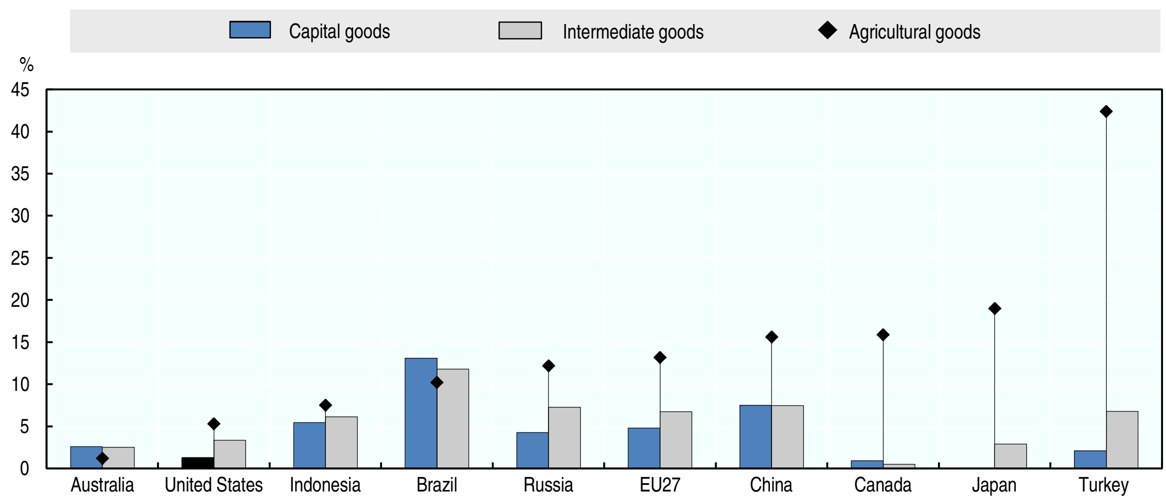
1. Simple average MFN tariffs, specific duties in *ad valorem* equivalents included. Tariff rates for non-agricultural products do not include *ad valorem* duties.

Source: WTO (2015a), "Tariff Profiles – United States". http://stat.wto.org/TariffProfiles/US_e.htm.

StatLink http://dx.doi.org/10.1787/888933408824

Industries that use commodities as inputs may face higher tariffs for imported inputs than those that use imported machinery. Average applied MFN tariffs for machinery and manufactures range from 1.3% to 2.5%, while tariffs for commodity inputs are somewhat higher, at 7.3% for oilseeds, 11.7% for sugars, and 3.0% for cereals. As Figure 6.12 shows, tariffs on capital and intermediate goods do not raise significantly the costs of imported farm inputs.

Figure 6.11. Import tariffs for industrial and agricultural goods[1], 2012



1. Simple average MFN tariffs, specific duties in *ad valorem* equivalents included. Tariff rates for non-agricultural products do not include ad valorem duties.

Source: UNCTAD (2013), Trade Analysis Information System (TRAINS) and WTO (2015b), www.wto.org/english/res_e/publications_e/world_tariff_profiles15_e.htm.

StatLink http://dx.doi.org/10.1787/888933408834

Other barriers to trade may exist in the form of non-tariff measures (NTMs), which are any policies or standards that may restrict trade. These may include sanitary and phytosanitary regulations that differ from production processes used by trading partners, different product standards (for example, railroad gauges sizes that differ or the use of right hand vs left hand drive cars), or outright import bans based on concerns about invasive plant pests or animal diseases. In the United States, imported agri-food products require import licences and are subject to quarantine and inspection in order to protect domestic agriculture from the entry of pests and diseases, and to protect endangered plant species (Chapter 4). Bilateral and multilateral trade agreements often include mutual recognition of agri-food standards.

The United States has negotiated a number of trade treaties with its partners, and these treaties generally have the goal of reducing barriers to trade, such as tariffs, TRQs, and non-tariff measures (NTMs). Agricultural trade barriers are often more difficult to negotiate than barriers in other sectors of the economy, as agricultural barriers govern sensitive goods like foodstuffs and complicated sanitary and phytosanitary regulations. The United States is currently evaluating the Trans-Pacific Partnership (TPP) agreement, a trade treaty proposed by a group of Pacific Rim countries, and is negotiating the Trans-Atlantic Trade and Investment Partnership (TTIP) agreement with the European Union. USDA and other analysis indicate that these agreements may lead to modest gains in overall agricultural trade.

The 2014 Farm Bill continues authorisation for several export assistance and development programmes administered by USDA's Foreign Agricultural Service (FAS). The Market Access Program, the Foreign Market Development Program, the Emerging Markets Program, and the Technical Assistance for Specialty Crops Program partner with US producers, exporters, private companies, and other trade organisations to finance activities promoting generic US agricultural commodities. Activities include consumer promotions, market research, technical assistance, and trade servicing for agricultural products, as well as technical assistance to US exporters in addressing phytosanitary or other technical barriers that inhibit trade. FAS also administers the Export Credit Guarantee (GSM-102) programme that provides credit guarantees for financing of commercial exports of US agricultural products.

Several food security programmes provide for the donation of US agricultural commodities for feeding and to be sold to support agriculture and food-related development programmes. The McGovern–Dole International Food for Education and Child Nutrition Program provides for the donation of US agricultural commodities, as well as financial and technical assistance, to support school feeding and maternal and child nutrition projects. The Bill Emerson Humanitarian Trust makes funds available in crisis situations to purchase appropriate US commodities based on availability and specific needs. The Food for Progress Program donates US agricultural commodities to recipient countries to be sold on the local market, with proceeds used to support agricultural, economic or infrastructure development programmes. The Food for Peace Program, administered in conjunction with the US Agency for International Development, provides US commodities, as well as local and regionally procured foods, cash transfers and vouchers for emergency feeding and for use in supporting related food security development programmes.

Agricultural support level and composition

Level and composition of support to producers

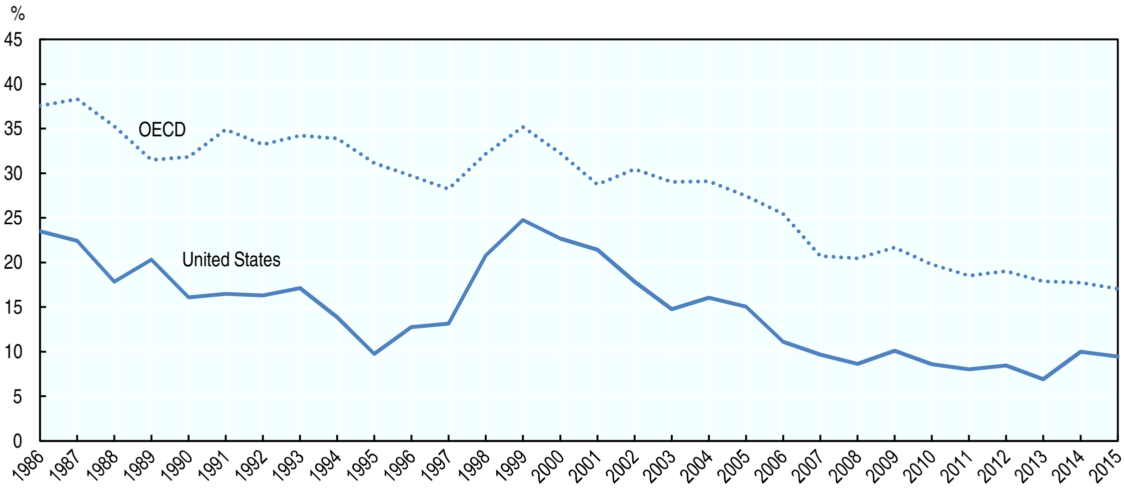
OECD indicators of support to agriculture offer a means of identifying the amount of support to producers and share of producer receipts provided by government policies (the Producer Support Estimate, or PSE, and the PSE as a percentage of gross farm receipts, or %PSE). The US %PSE has been consistently below the OECD average, peaking at 25% in 1999, when the OECD average was 35%, and falling steadily since then to a low 7% in 2013 and 9% in 2013-15, compared to the OECD average of 18% (Figure 6.12). As a number of US commodity programmes are countercyclical, years of high commodity prices result in lower levels of support, which accounts in part for the low %PSE levels since 2007 (Figure 6.13).

The PSE classifies policies providing transfers to producers on the basis of implementation criteria, which are recognised as having varied impacts on production, trade, income, and the environment. While the PSE categories do not measure the impacts of different policy types, they identify criteria generally considered to be of economic significance. Examining the composition of the PSE reveals the extent to which producers are supported through policies with the strongest influence on production incentives and thus most likely to distort markets, which include support based on commodity output and input use without constraints on agricultural practices.

US support to producers based on commodity outputs has fallen markedly over the last several decades, from a high of 16% of the value of agricultural production to a recent average of 1.5% (Figure 6.14). Output-based and input-based support accounted for an average of 48% of the US PSE in recent years (2013-15), compared with an OECD average of 60%. A growing share of input-based payments in the United States is tied to adoption of practices to reduce agri-environmental impacts, which are considered to be among payments less likely to distort markets. If those input payments are removed from the input-based support total, the share of potentially most trade distorting support falls to 31% of the US PSE, compared to 51% of the OECD average (Figure 6.15).

Figure 6.12. US Producer Support Estimate (PSE) compared to OECD average, 1986-2015

PSE as a percentage of gross farm receipts



Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

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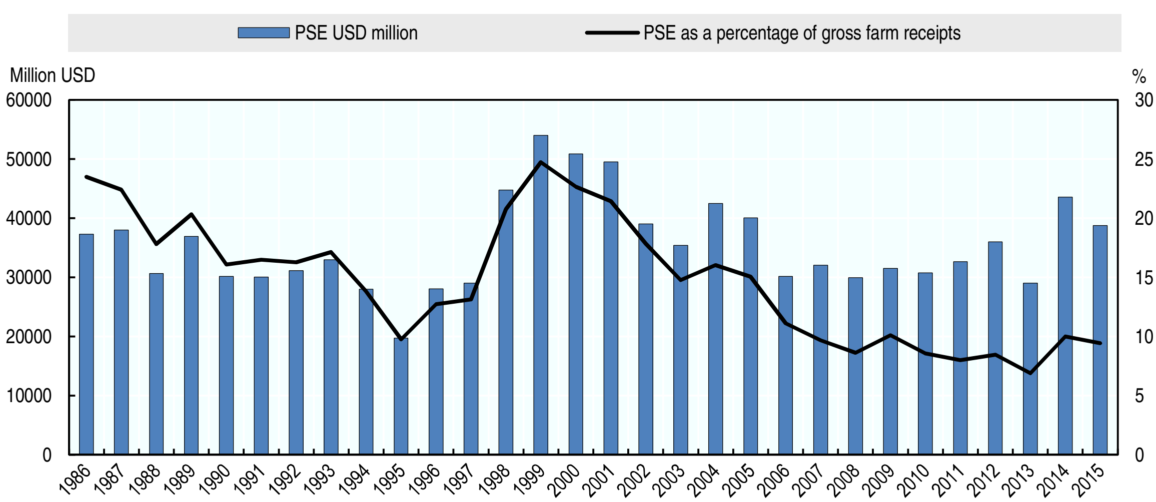
Figure 6.13. Variations in US Producer Support Estimate (PSE) over 1986-2015

In million USD and as a percentage of gross farm receipts



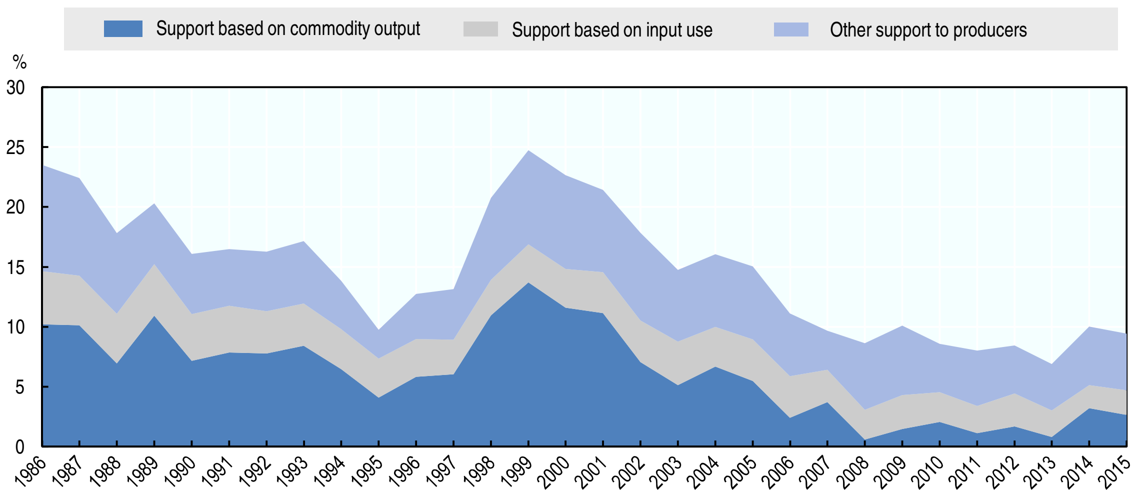
%PSE is the Producer Support Estimate (PSE) as a percentage of gross farm receipts.

Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink http://dx.doi.org/10.1787/888933408853

Figure 6.14. Composition of support to US producers, 1986-2015

PSE as a percentage of gross farm receipts



Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

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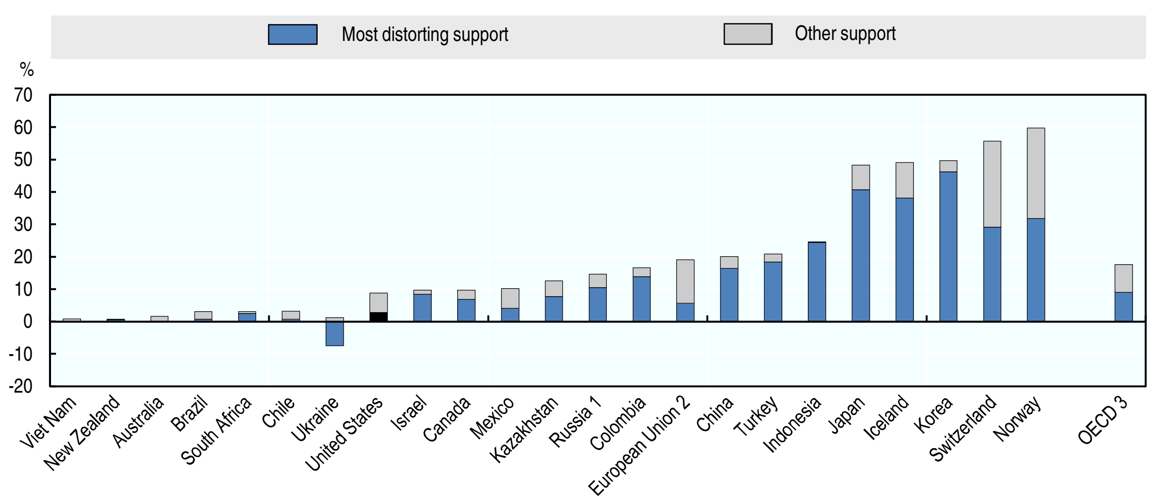
Figure 6.15. Composition of Producer Support Estimate by country, 2013-15

As a percentage of gross farm receipts



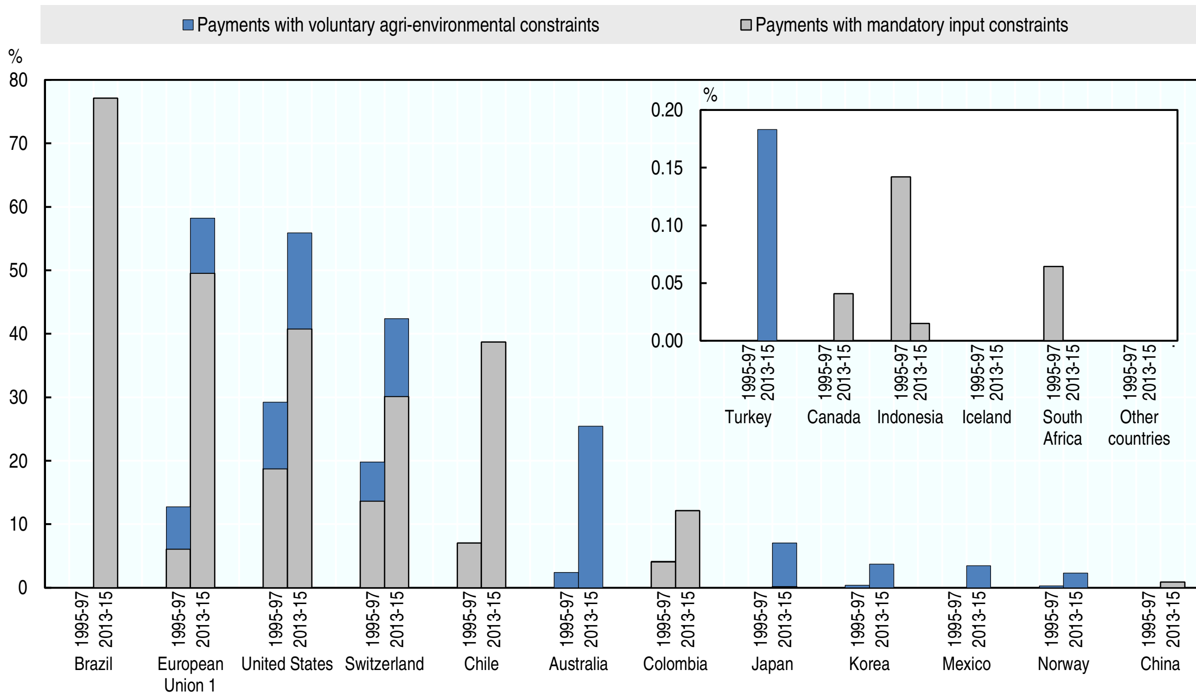
1. For Russia, 2013-15 is replaced by 2012-14.
2. EU27 for 2012-2013; and EU28 from 2014 when available.
3. The OECD total does not include the non-OECD EU member states.

Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink http://dx.doi.org/10.1787/888933408870

Figure 6.16. Support conditional on the adoption of environmentally friendly production practices, 1995-97 and 2013-15

As a percentage of total PSE



Countries are ranked according to 2013-15 levels.

1. EU15 for 1995-97; EU27 for 2012-13 and EU28 from 2015 when available.

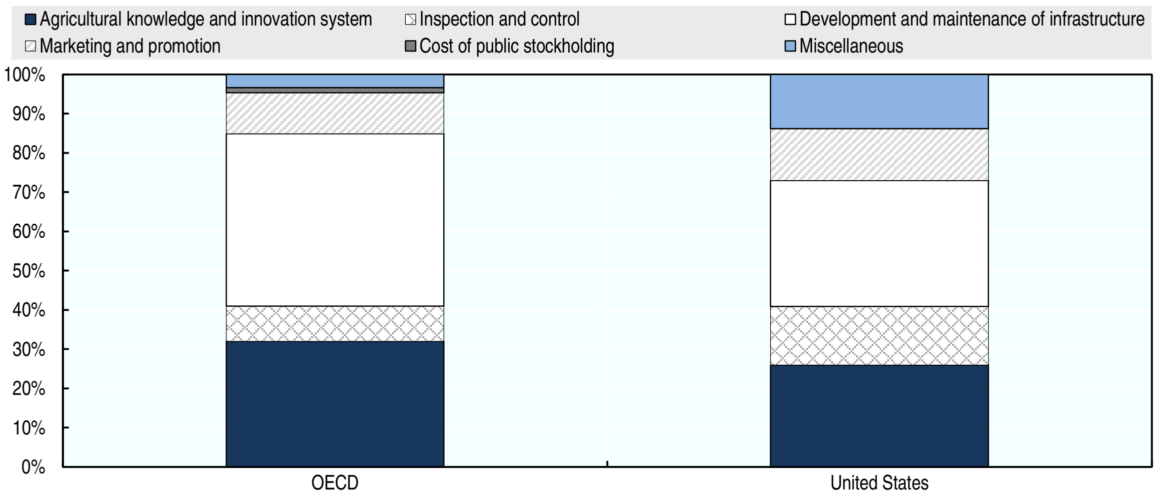
Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink http://dx.doi.org/10.1787/888933408889

Support conditional on the adoption of environmentally-friendly production practices has increased as a share of total support to producers, reaching 56% in 2013-15, close to that in the European Union, and much higher than in other OECD countries. With the European Union and Switzerland, the United States is one of the countries that use both mandatory and voluntary programmes to incentivise environmentally-friendly production practices (Figure 6.16).

Support to producers based on policies that require the production of a specific commodity can also introduce distortions by encouraging producers to plant the supported commodities rather than other commodities that might be in more demand. OECD's single commodity transfer (SCT) indicator measures the share of producer support provided on the basis of production of a specific commodity.[4] US SCT support has fallen from 16% of gross farm receipts in 1986-88 to 4% in 2013-15. However, the share of commodity-specific transfers in the gross farm receipts of each commodity varies across commodities. In 2013-15, sugar had the highest share, around 25%, with milk and cotton having shares higher than 10%. The US %SCT remains low compared to the overall OECD average, which was 10% for 2013-15. However, the SCT represented 43% of the total PSE in 2013-15, primarily as a result of premium subsidies under insurance programmes, which are commodity-specific, but also because of price support in the case of sugar, milk, beef and sheep meat. The average share is higher than in the European Union (28%), but lower than the OECD average of 53%.

Figure 6.17. Composition of US GSSE compared with OECD average, 2013-15



Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

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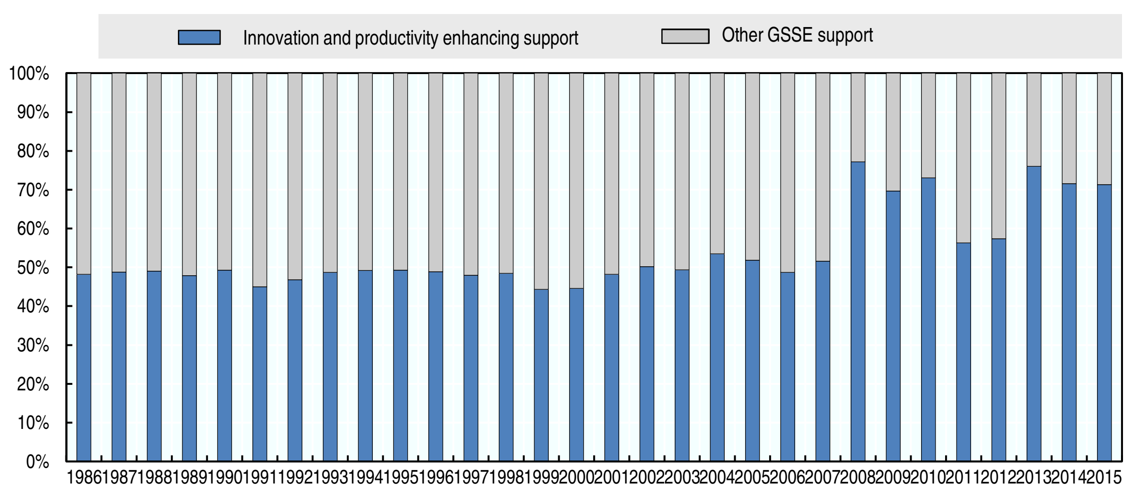
Figure 6.18. Composition of US Estimate of Support to General Services, 1986-2015



Innovation and productivity enhancing support include agricultural knowledge systems, inspection and control, and infrastructure; other GSSE support includes marketing and promotion, public stockholding, and miscellaneous.

Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink http://dx.doi.org/10.1787/888933408900

Two other indicators reflect the share of producer receipts that result from market prices that are higher than they would be without domestic support and border policies. The Nominal Protection Coefficient (NPC) compares the prices received by domestic producers with unsupported, or world, prices (farm-level equivalent border prices), while the Nominal Assistance Coefficient (NAC) compares producer gross receipts with what they would be at unsupported, or world, prices (farm-level equivalent border prices). The closer the NPC is to 1.0, the closer prices received by farmers are to global prices, and the closer the NAC is to 1.0, the less farm receipts are supported by domestic policies. For 2013-15, the US NAC averaged 1.10 and the NPC 1.02, compared with the OECD average of 1.21 and 1.10 (OECD, 2016b). Most commodity prices are aligned with world prices, with the exception of sugar prices (25% higher in 2013-15, milk prices (11%), sheep meat prices (9%) and to a lesser extent beef prices (3%).

The General Services Support Estimate (GSSE), companion to the PSE's measure of support to individual producers, identifies support by government to the farm-level agriculture sector more generally. Much of this support works to enhance innovation and productivity, improving the long-term competitiveness of the sector by supporting agricultural knowledge and innovation systems, inspection and control systems, and infrastructure. The US GSSE has provided the largest share of GSSE support to the agricultural knowledge and transfer system in recent years — 26%, compared to support 15% for inspection and control, 32% for infrastructure development, and 13% for marketing and promotion on average for 2013-15 (Figure 6.18). The United States provided less than 1% of GSSE support for the cost of public stockholding. For the OECD as a whole, the average shares for 2013-15 were 32% for agricultural knowledge transfer, 9% for inspection and control, 44% for infrastructure development, 10% for marketing and promotion and 1% for stockholding (Figure 6.17).

Agricultural knowledge and innovation, inspection and control, and infrastructure are services enhancing innovation and productivity in agriculture. Agricultural knowledge and innovation and some infrastructure can also improve sustainability. These services accounted for about half of GSSE expenditure until 2008 when their share increased significantly (Figure 6.19). It remains, however below the OECD average (Figure 6.19B) Moreover, the GSSE accounts for a relatively small share of total support to agriculture as shown in Figure 6.19A and discussed below.

Total support to agriculture is measured by the Total Support Estimate (TSE), which includes the PSE and GSSE already discussed above, as well as an estimate of transfers from taxpayers to consumers through consumer support policies, which may include support to first handlers of commodities as well as social assistance programmes that provide direct support for food purchases, which may enhance demand for agricultural commodities. US TSE represents 0.5% of GDP in 2013-15, compared to 0.7% in the European Union and the OECD average (Figure 6.19A). This means support to agriculture places a lower burden on the US economy than in these groups of countries.

In the United States, the share of transfers from taxpayers to consumers in the TSE is unusually large — 48% compared to 14% on average in the OECD area in 2013-15, as a result of US domestic food assistance programmes, especially the Supplemental Nutrition Assistance Program (SNAP), which are reported in this category (Figure 6.19A). Conversely, the PSE is a smaller component of the TSE in the United States (43%) than in the OECD average (73%). The GSSE accounts for a modest share in both cases: 10% in the United States and 14% in the OECD area. In countries with a larger share of GSSE in the TSE such as Australia, Chile and New Zealand, this is associated with low PSE levels.

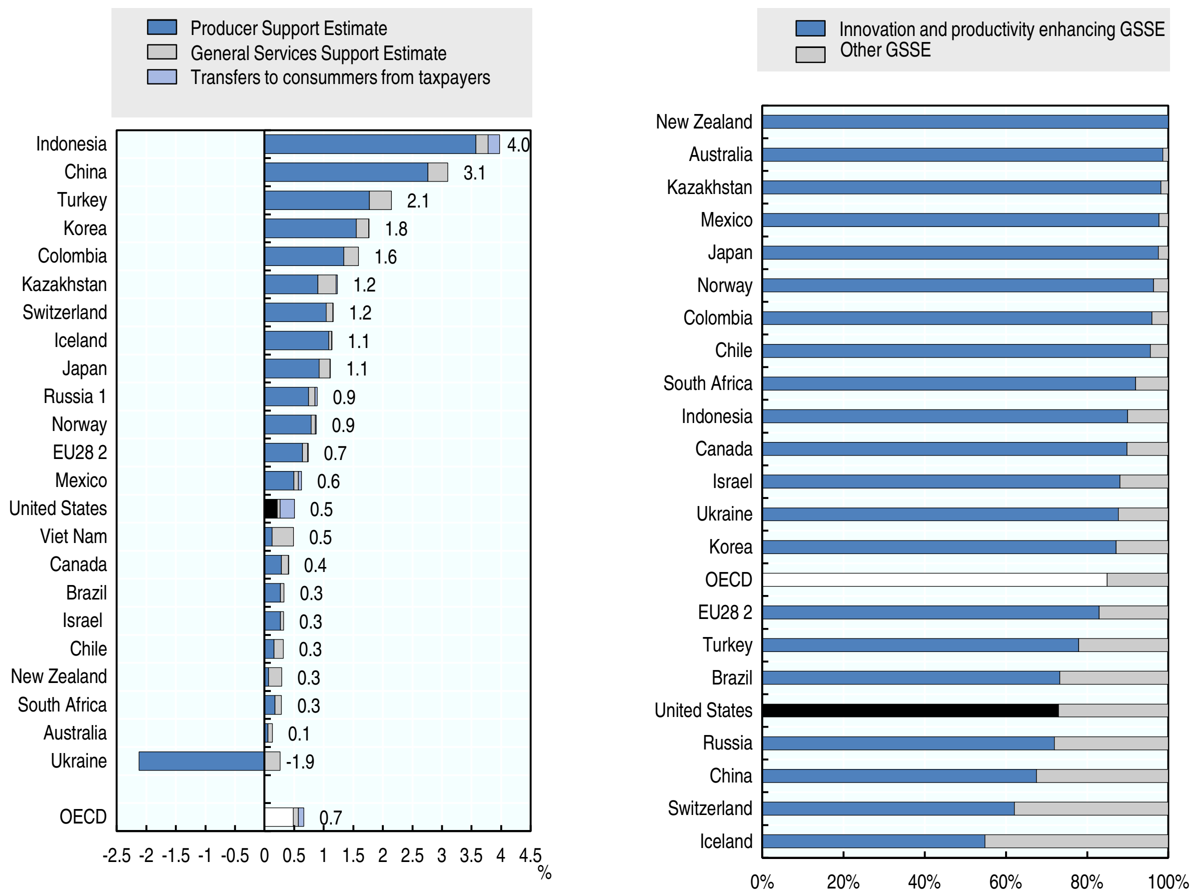
Figure 6.19. Total support to agriculture (TSE) and general services (GSSE) by country, 2013-15

A. Composition of total support to agriculture (TSE)

As a percentage of GDP

B. Share of innovation and productivity enhancing services in the GSSE

As a percentage of total GSSE



1. For Russia, 2013-15 is replaced by 2012-14.

2. EU27 for 2012-13 and EU28 from 2014 when available.

3. Innovation and productivity enhancing support include agricultural knowledge systems, inspection and control, and infrastructure; other GSSE support includes marketing and promotion, public stockholding, and miscellaneous.

Source: OECD (2016a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink http://dx.doi.org/10.1787/888933408916

Discussion of likely impact

Domestic agricultural and associated trade measures affect farm investments and practices through a variety of instruments, with different impacts on structural change, sustainability and innovation.

OECD analysis has shown that measures that distort input and output markets, such as border protection, supply controls, output-based payments and variable input subsidies, reduce producers' incentives to use production factors more productively (OECD, 2012). As such, they hinder structural adjustment and discourage producers for innovating to become more competitive. These distorting measures can maintain resources in the sector that would otherwise be reallocated to more productive uses; they can encourage more intensive production, sometimes on marginal or fragile land; and they can encourage production practises that do not always take adequate consideration of longer term environmental sustainability.

Broad-based income support decoupled from commodity production is more effective in transferring income to producers and thus increasing their capacity to invest and innovate. It also leaves more flexibility to producers to undertake new activities and switch to new products. However, even if decoupled from production choices and targeted, income support slows structural adjustment needed to facilitate economies of scale, attract new entrants and thus foster innovation and productivity growth. If conditional on the adoption of environmentally-friendly practices, this support can improve sustainable resource use.

Agricultural measures that support innovation directly are likely to create stronger incentives and capacity for innovation among agricultural producers and will help structural change. Similarly, agri-environmental payments that target explicitly the desired environmental outcome would steer farmers towards innovative sustainable practices more effectively (OECD, 2015).

US farm policies may affect farm structure, innovation, and resource use, but overall impacts are difficult to measure, not only because of changes in policy designs, but also because market and other factors also affect farmers' behaviour. Structural change has been ongoing in the United States since the 19th century at least, resulting first from land availability through westward expansion and later from productivity growth and non-farm economic opportunities that attracted labour away from farming (Dimitri et al., 2005). Farm consolidation and productivity growth accelerated in the mid-20th century at about the same time that US price support programmes began, leading some to argue that policy supported structural change and productivity growth. However, research suggests that policies have been secondary to the impacts of science on innovations that spurred each (Gardner, 2002).

Agricultural policy places few restrictions on structural adjustment in farming, with some exceptions: Marketing orders apply for a number of commodities, notably milk, and some fruits and vegetable: Ten retain volume control options, but only one has had active volume controls in recent years (Box 4.1). Sugar marketing allotments place limits on production, which have not been binding in recent years. Supply controls were more widely applied in the past. Federal peanut and tobacco programmes relied on marketing quotas to regulate production and to support prices paid to producers. The transfer of the rights among farmers was restricted to narrow geographic areas, and after the programmes were terminated in the early 2000s, production shifted rapidly to different geographic areas and consolidated onto larger farms (Box 4.1).

NPCs show that sugar and milk policies still raise domestic prices above world level (by 18% for milk and 78% for sugar in 2015, a year characterised by lower world prices). These distorting measures can maintain resources in less productive areas, as shown in the case of peanuts and tobacco. As they distort incentives across commodities, they also maintain resources in supported commodity sectors, as does all commodity-specific support.

Direct income support programmes have evolved historically to reduce the effects of programmes on markets, by linking a larger share of support to historical rather than current parameters. At the same time, crop insurance programmes have offered more coverage options to producers to take account of diverse risk exposure and behaviour.

As most support is linked to planted or historical area, a greater share of farm programme benefits accrues to larger producers who farm more land (White and Hoppe, 2012; MacDonald et al., 2013). Since most cropland is rented, especially on larger farms, payments based on land are capitalised into land values, leading to a shift of benefits from farm operators to landowners.

Some research has investigated the impact of broad-based commodity support on farm consolidation. Cropland consolidation, summarised at the national level in Table 2.3, has proceeded more rapidly in those US counties with higher levels of commodity programme support, measured in terms of average payments per cropland acre in the county (Key and Roberts, 2007). Farms in those counties have also been less likely to exit farming than farms in other counties. However, counties with high levels of payments also have large, relatively flat, and contiguous fields where the labour-saving mechanical and chemical technologies on the last 40 years have been most effective (MacDonald et al., 2013). In addition, consolidation has also proceeded rapidly in livestock and in specialty crop commodities, which receive no support under commodity programs (Table 2.3). At the least, research has so far not successfully identified impacts of commodity policies separate from the impacts of labour-saving innovations on consolidation.

Policy measures that reduce income variability may have encouraged risk-averse farmers to innovate in response to market incentives, as incomplete risk markets are expected to prevent them from making optimal decisions. Conversely, these measures may crowd-out prevention efforts, which may include innovation (e.g. drought-resistant seeds). The net effect would be difficult or impossible to assess, all the more because attitudes to risk vary among farmers.

Programme benefits may have provided resources for adopting new technologies,[5] but not necessarily to those who needed assistance to invest, as payments are not linked to income needs (OECD, 2003). It would be difficult to assess the share of investment in new technologies that would not have occurred in the absence of policies. Moreover, programme benefits may not have been used to invest in the farm business, and some may have even left the sector.[6] US data on investment by farmers receiving decoupled payments (Production Flexibility Contracts) over 1996-2001 show no evidence of higher rates of on-farm investment or capital replacement compared to farmers, who did not participate in the programme (Burfisher and Hopkins, 2003). Further research found that US decoupled payments have increased household wealth, but have led to no or very modest changes in farm operating decisions (Goodwin and Mishra, 2006; Weber and Key, 2014 and 2015). It seems thus that they had negligible effects on the adoption of innovations or farm productivity.

Historically, US farmers have readily adopted new technologies, both to improve yields and to reduce costs and dependence on often scarce farm labour (Wang et al., 2015). These developments have occurred alongside a variety of types of producer support — from market price supports, to target price/deficiency payments that separated assistance from market prices, to decoupled income support that made assistance independent of production decisions, and to crop insurance programmes that tailor support to farm-level losses and producer risk preferences. Besides possible income and risk effects, perhaps key to this continuing openness to innovation and the high productivity achievements has been the very low barriers to expanding production in response to market signals. While programmes included acreage reduction provisions until 1996, producers have continually retained the freedom to increase yields and alter input choices on active acreage without affecting commodity or income support levels.

Government support may also have facilitated further expansion of farm operations. US evidence shows that cropland consolidation has proceeded more rapidly in those counties with higher levels of government commodity programme payments per acre (Key and Roberts, 2007). However, consolidation has proceeded rapidly in livestock and specialty crop commodities that receive no support, and counties with high levels of payments also have large, relatively flat, and contiguous fields where labour-saving technologies are best placed (MacDonald et al., 2013).

The impacts of farm programmes on resource use are mixed, affecting both extensive (expansion or reduction of cultivated land) and intensive margins (input use intensity); and these impacts themselves likely interact through price effects. From a historical perspective, soil conservation provisions have been an integral part of US farm programmes since they began in the 1930s. On the other hand, unrestricted production intensification –through adoption of new technologies–have frequently included expanded use of resources, especially of manufactured inputs and energy.

Crop insurance programmes may have specific environmental impacts through their effects on input use (e.g. fertilisers and chemicals), crop acreage, and decisions to expand cultivation to marginal land. In particular, crop insurance subsidies, by reducing the cost of the risk born by farmers, may in principle increase the incentive to adopt risky practices, such as monoculture or high risk crop varieties. Several studies conducted in the United States tend to confirm the existence of such effects, although they suggest their magnitude may be small (Horowitz and Lichtenberg, 1993; Smith and Baquet, 1996; Wu, 1999; Goodwin et al., 2004; O'Donoghue et al., 2009; Walters et al., 2012; Claassen et al., 2015; Weber et al., 2015). Implementation provisions of crop insurance programmes may influence production practices through control of moral hazard and claims verification and by reducing insurance costs through reinsurance and reimbursement of administrative and operating expenses for providers. These potential influences are difficult to include in assessments, complicating interpretation of the effects of crop insurance programmes.

The development of cross-compliance and voluntary conservation programmes has partly contributed to reduce soil erosion and environmental impacts of agriculture since the 1980s.[7] There exists quantitative evidence that both cross-compliance and voluntary conservation programmes have indeed encouraged the adoption of environmentally-friendly practices, although several other explanatory factors have also been pointed such as technology, information and markets (Claassen et al., 2004; Claassen et al., 2014).

Cross-compliance mechanisms have partly contributed to reduce soil erosion since the 1980s by encouraging farmers to use less erosive cropping practices (e.g. conservation tillage, conservation crop rotations) and to retire particularly erosive land (CRP). Cropland soil erosion declined by 40% between 1982 and 1997 (Figure 2.15), and it is estimated 25% of this decline is directly attributable to cross-compliance incentives (Claassen et al., 2004). Erosion reduction on land subject to cross-compliance erosion mitigation requirements (28% of all cropland) accounted for more than 50% of the soil erosion reduction on land that was continuously cropped during that period (i.e., not entered into CRP or otherwise removed from crop production) (Claassen et al., 2004).[8]

Voluntary conservation programmes have encouraged farmers to adopt more environmentally-friendly practices, and address a broader set of environmental objectives. Analysis of conservation practices added by farms participating in voluntary conservation programmes indicated probabilities of around 80% that these producers would not otherwise have adopted conservation structures and buffer practices. However, additionality is closer to 50% for conservation tillage and there is less clear evidence regarding adoption of nutrient management plans and their practical implementations (Claassen et al., 2014). Conservation programmes not only address soil erosion but also manure management and nutrient runoff, air quality, wildlife habitat, and preservation and restoration of wetlands, grasslands, and riparian buffers.

Despite these encouraging results, there are still several issues and challenges regarding the design and performance of agri-environmental programmes: 1) There exists evidence that sustainability performances could be further improved, in particular in terms water use, and pollution, and that market mechanisms, regulations and incentives used to promote more sustainable use of resources have not solved acute local problems; 2) Additionality of conservation programmes may be lower for certain practices; 3) Conservation programmes, by increasing profitability of farming, may have indirect land-use and input use effects, which can in turn worsen environmental performances — the so-called "slippage effect" (Wu, 2000; Roberts and Bucholz, 2005; Lichtenberg and Smith-Ramirez, 2011; Fleming, 2014; Uchida, 2014; Lichtenberg, 2014); 4) Targeting and tailoring mechanisms such as the Environmental Benefit Index could be further refined and expanded; and 5) research continues to suggest that commodity and crop insurance programmes encourage crop production on a small but measurable amount of land that would otherwise not be used for crop production (Claassen et al., 2011).

Summary

- Agricultural legislation (Farm Bill) includes programmes related to commodity support, conservation, trade, nutrition (domestic food assistance), agricultural credit, rural development, research and extension, energy, specialty crops, and crop insurance. It is established for five years, but can be extended.

- The largest and growing share government expenditure under the Farm Bill supports nutrition programmes, which are projected to receive 80% of projected outlays over 2014-18 (2014 Farm Bill).
- Commodity programmes fall into three broad categories: market price support, direct income support, and risk management. Since the reform of dairy policies in 2014, sugar is the only market price support programme remaining. Sugar price support is maintained through a system of marketing allotments, nonrecourse loans, and tariff-rate quotas on imports.
- Direct income support includes both benefits based on output and payments based on historical production parameters. They are designed to reduce farm revenue annual variability by offering payments when prices or revenues based on historical production parameters fall below the minimum coverage. Risk management programmes include crop yield or revenue insurance schemes, where government subsidises premiums and reinsures private insurance providers. Direct income support programmes have evolved historically to reduce the effects of programmes on markets, by linking a larger share of support to historical rather than current parameters. Over the same period, crop insurance programmes have offered more coverage options to producers to take account of diverse risk exposure and behaviour.
- Marketing orders remain for milk and more than 20 fruits and vegetable, but marketing allotments that limit marketing volumes have not been used in recent years, except for one product.
- Agri-environmental incentives include mandatory conservation compliance for participants in most farm programmes, and voluntary programmes that include both land retirement and the adoption of land preservation and environmentally-friendly production practices on working land. Producers may receive technical assistance to implement conservation practices. Innovation grants are also available to fund innovative projects as part of one programme (EQIP)
- Agri-environmental programmes originally focused on soil quality and water quality and conservation. These objectives have expanded to include wildlife habitat, air quality, carbon sequestration, energy conservation, and preserving farm and ranch lands. At the same time, programmes have become increasingly focused on working lands and away from land retirement, although targeted land retirement remains an important programme component. Conservation spending on working land are planned to rise above 50% of all conservation spending over 2014-18. These programmes have encouraged farmers to adopt more environmentally-friendly practices, but there remains room for improving policy design and environmental performances in this area.
- As part of federal efforts to prepare for adaptation to climate change, each federal agency is required to develop a specific plan addressing the challenge of climate change adaptation in the frame of its goals and activities. USDA reviewed climate change impacts on agriculture, and analysed adaptation and policy responses in this area. It also launched seven Regional Climate Hubs, which are expected to help farmers in their choices for adapting to climate change.
- Bioenergy programmes are designed to provide incentives for research, development and adoption of renewable energy, including solar, wind, and anaerobic digesters, but primarily biofuels. Programmes provide assistance for research and development of advanced biofuel feedstocks, conversion of energy systems to use alternative feedstocks, and assistance to producers to establish and maintain production of non-commodity biomass feedstocks and biobased products, using establishment and annual payments, and investment loans and grants depending on the programme. Assistance to developing and expanding markets for biobased products include mandatory biobased supplies and services procurement, and mandates for blending biofuels, as well as loan guarantee for biobased production facilities and tax credit for biodiesel blenders.

- Agricultural tariffs are slightly above the average for non-agricultural products but more than three-quarters of applied tariffs are under 5%. Higher tariffs (between 10 and 20%) apply to dairy products, sugar and confectionary products and beverages and tobacco, and tariff rate quotas for certain products in these categories, and for animal feed and certain fruits, impose much higher tariffs for quantities above the import quota.
- Non-tariff measures include import licencing and quarantine and inspection of imported agri-food products, aiming to protect domestic agriculture from the entry of pests and diseases, and to protect endangered plant species.
- Several trade assistance and development programmes fund export promotion, market research, technical assistance (including to manage sanitary and phytosanitary requirements in other countries) and trade services, and credit guarantee is available for financing commercial exports of US agri-food products. In addition, several food security programmes provide for the donation of US agricultural commodities. The share of US agri-food trade exported under these programmes has significantly declined since 1995.
- Close to half of total support to agriculture as measured by the OECD's Total Support Estimate accrues to consumers via Farm Bill nutrition programmes, which are hardly linked to farm productivity and sustainability performance.
- Support to agricultural producers accounts for over 40%, while support to general services such as research, education and extension, inspection, agriculture-related infrastructure and promotion of agricultural products account for about 10% of the total. Among general services, those enhancing innovation and productivity account for about three-quarters of the total.
- Support to producers varies over time, reflecting the counter-cyclical nature of US programmes, but it consistently accounts for a lower share of gross farm receipts than the OECD average. Most of US support is conditional on the adoption of conservation practices and over 40% is commodity-specific.

Notes

1. Ethanol plants in operation or under construction by the end of 2007 are not required to meet the 20% reduction requirement.
2. In the 2014-16 Final Rule, the biomass-based diesel mandate was raised to 1.63 billion gallons for 2014, 1.73 billion gallons for 2015, 1.90 billion gallons for 2016, and 2.0 billion gallons for 2018. While the mandate in 2022 could be lower than it is currently, that seems unlikely.
3. Tariffs rates are simple averages across tariff lines.
4. The SCT measures support for wheat, barley, maize, sorghum, alfalfa, cotton, rice, soybeans, refined sugar, milk, beef and veal, pigmeat, poultry meat, sheepmeat, eggs, and wool.
5. OECD work on decoupling (OECD, 2006) suggests that agricultural support that raises and stabilise income affects investment. More decoupled payments were found to have more impact on investment than price, mainly through risk-reduction, but the relative impact of different types of measures on investment is difficult to assess.
6. USDA data on Farm Household Income and Characteristics show that, on average, US principal farm operator household hold significant non-farm assets. Non-farm net worth has increased faster than farm net worth between 2010 and 2014, and accounted for over 40% of US principal farm operator household total net worth in 2014.

7. The HELC provisions and the CRP were enacted in 1985. The CRP began enrolling land in 1986 and reached full enrolment by the early 1990s. Although CRP did not focus exclusively on reducing soil erosion, a great deal of erosion-prone cropland was enrolled. By 1995, HELC required the application of an approved soil conservation system on “highly erodible” cropland as a condition of continued eligibility for most Federal agriculture-related benefits.

8. Roughly 30% of US cropland is defined as “highly erodible” for wind or rainfall erosion based on soil, topography, and climatic conditions. A large majority of this land (roughly 85%) is located on farms that receive some type of payment that could be denied under HELC (Claassen et al., 2004). Claassen et al. (2004) estimate that 56% of that reduction occurred on land that was subject to HELC or retired from crop production through CRP enrolment. Another 11% was due to the overall net reduction in cropland area (other than through CRP enrolment). The remaining erosion reduction (33%) occurred on cropland not subject to HELC but continued in crop production.

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Chapter 7

THE US AGRICULTURAL INNOVATION SYSTEM

This chapter describes the US Agricultural Innovation System in relation with the general innovation system, outlining how it adjusted to changes in the global science landscape. It presents main actors and their roles in the system, and provides an overview of governance mechanisms. It also describes main trends in public and private investments in R&D, and discusses complementarities and changes in funding mechanisms. It provides an overview of policy incentives for fostering innovation, outlining the role of farm extension, Intellectual property rights, tax incentives and public-private partnerships, and reports evidence on R&D outputs and impacts, as well as examples of adoption of innovation. Finally, the role of US agricultural science in international co-operation is discussed.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Foundations of the US agricultural innovation system

By the middle of the 20th Century, the United States had emerged as the global leader in agricultural science and technology. Through a federal-state partnership, it had developed an integrated research-extension-education system (Box 7.1). Not only did this contribute to produce an internationally competitive farm sector, but agricultural science and technology itself became an export industry. Agribusiness suppliers of improved farm inputs — crop seeds, animal breeds, agricultural chemicals, and farm machinery — developed export markets for their products, and agricultural universities attracted numerous foreign students for advanced study.

Over the ensuing decades the US agricultural innovation system has adjusted to a changing global landscape for science and technology. This chapter focuses on three major developments to this landscape and how US agricultural science policy, particularly at the federal level, has responded. First, major scientific advances in biological and computation sciences have led to the emergence of a "*New Biology*".[1] In response, the agricultural research system has sought to forge stronger linkages with these sciences and develop applications for food and agriculture. Second, there has been major growth in the agricultural research and development (R&D) capacities of the private sector. Whole classes of farm technologies that were once the purview of the public sector are now developed and disseminated by commercial firms. The public system has needed to redefine its role and forge stronger linkages with commercial R&D capacities. Third, as science and technology capacities of other countries have grown, the relatively dominance of the US system has declined. This has opened up new possibilities for international scientific partnerships to work on common challenges. At the same time, the United States has continued to help build agricultural innovation capacity in low income countries as part of its historical commitment to achieving global food security.

Box 7.1. Foundations of the public agricultural innovation system in the United States

US public agricultural research began with federal efforts in the late 18th Century to collect seeds and plants from around the world and distribute them to American farmers to test for their suitability for US agricultural conditions. Starting in 1819, seed collection was organised by the Patent Office. In 1862, the US Department of Agriculture (USDA) was established as an agency within the executive branch of the Federal government and took over this function from the Patent Office. The USDA greatly expanded seed collection and distribution, as well as the gathering of agricultural statistics. While broadly conceived, USDA's initial focus was to procure, test and distribute new plants and seeds; to diffuse useful information on subjects connected with agriculture; and to raise the productivity of US agriculture.

In the same year, the Morrill Act of 1862 created the Land Grant Colleges (so named because they were funded using sales of public land). Congress saw the need to establish educational institutions in each state, focused on practical studies in agriculture and the domestic and mechanical arts. While initial funding came from the federal government, the Land Grant Colleges are governed and supported by the states.

Some states began to establish research programmes to facilitate the sharing of scientific knowledge among academics, and to disseminate their findings to agricultural producers. However, the need for a concerted, coordinated national approach was seen. The Hatch Act of 1887 provided federal funding to establish a State Agricultural Experiment Station (SAES) in each state, for the purpose of agricultural research, including problems of regional importance. Most SAES are part of or connected to the Land Grant Colleges. The USDA was raised to a cabinet-level department in 1889, and began reporting directly President. Intramural research by the USDA was significantly expanded in the late 19th and early 20th Centuries and provided scientific leadership for the federal-state agricultural research system. In 1953, agricultural research in the various USDA bureaus was consolidated into the newly formed Agricultural Research Service (ARS). ARS now employs more than 2 000 scientists in 90+ laboratories throughout the country.

Despite the steady gains in higher education and research programmes at the Land Grant Colleges and SAES, disseminating technical innovation to farmers remained an obstacle. The Smith-Lever Act (1914) created cooperative state extension services as a federal-state-local partnership. Based in land grant institutions, extension services specifically were designed to share the results of agricultural research with farmers, household managers and young people. Together, the Morrill Act, the Hatch Act and the Smith-Lever Act established the three legs of the US agricultural innovation system — education, research and extension.

Further federal legislation strengthened and expanded the system. The Bankhead-Jones Act (1935) provided increased federal funding to Land Grant Colleges, based on formulas based on states' populations. The Act also required that such federal funds must be matched by state governments. The matching requirement encouraged farmers to get more involved in their state Land Grant programs and lobby their state legislators to support them. The economic rationale for matched funding is that benefits of agricultural research often spillover across state boundaries. Left to themselves, states face an incentive to under-invest or "free ride" on other states' investments in agricultural research.

Other changes expanded the system to address needs of under-served populations and communities. A second Morrill Act of 1890 created separate Land Grant Colleges that did not discriminate on the basis of race in states that at that point did not admit African Americans to their land grant universities. The Equity in Educational Land-Grant Status Act of 1994 conferred land grant status to Tribal Colleges and Universities, which primarily serve Native Americans in remote and underserved communities, boosting federal funding for these institutions.

Source: This summary draws heavily upon Ruttan (1982) and Huffman and Evenson (1993).

Agriculture in the US research system

Agriculture has a unique history in US science and technology policy. Prior to the Second World War (WW II), agriculture was the only economic sector receiving significant federal government support for R&D. Legislation passed in the late 19th and early 20th Centuries — especially the Morrill Act (1862), the Hatch Act (1887) and the Smith-Lever Act (1914) — established a federal-state partnership to support agricultural education, research and extension (Box 7.1). As late as 1940, nearly 40% of total federal government R&D spending was for agriculture, with most of the remainder focused on national defence (Mowery and Rosenberg, 1989).

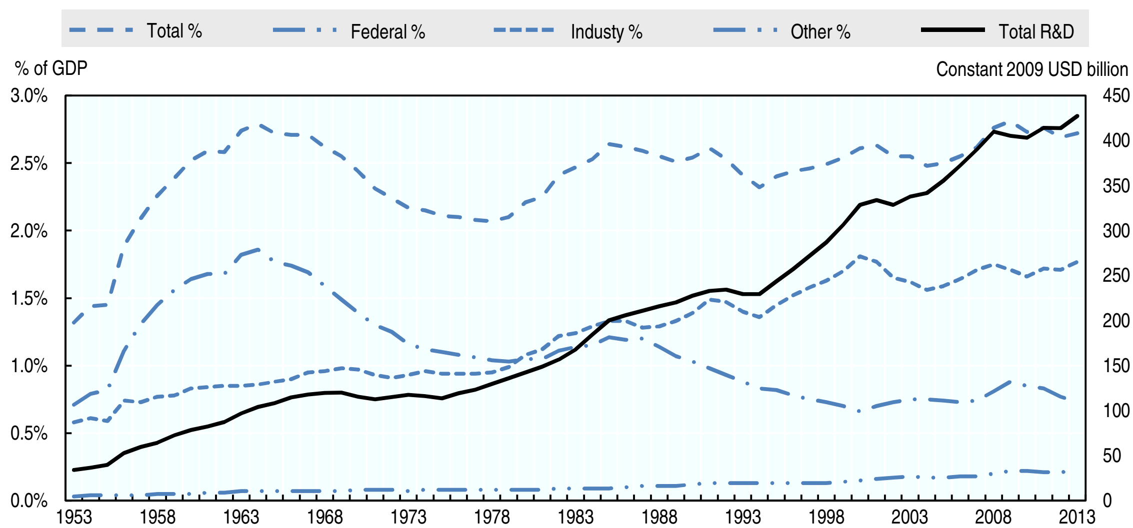
WW II transformed the US R&D system. During the war, the nation's university science and engineering communities were mobilised to support the development of new military technologies. As the war ended, the President's science advisor, Vannevar Bush, proposed a much larger role for the federal government in support of post-war scientific research. His report, *Science: The Endless Frontier* (Bush, 1945), established the new charter of US research policy. Government investment in research would contribute not only to national security but also to the development of new products, new industries and job creation. Subsequently, government funding for R&D rose quickly, and the United States became the pre-eminent world leader in scientific and technological discoveries.

The economic justification for the expanded government role in R&D was that the social returns to R&D exceeded the private returns by a wide margin (Nelson, 1959; Arrow, 1962). Much of the benefits of R&D would "spill over" to other firms and consumers. In other words, the creation of knowledge has the properties of a "public good" – it is non-rival (several individuals can consume it without diminishing its value) and non-excludable (once in the public domain, an individual cannot be prevented from making use of it). Since a firm could only capture a fraction of the total benefits of R&D, industry would significantly under-fund it. The market failure argument was originally formulated to justify public support for basic research. But economic studies have also found large gaps in the social and private rates of return to applied research for a wide range of industries (Hall, Mairesse and Mohnen, 2010), including agriculture (Pardey, Alston, and Ruttan, 2010). Thus, the private sector responding to market incentives is likely to significantly under-fund applied research as well (Ruttan, 2001).

US investment in research and development

Total government and private R&D spending as a percentage of GDP doubled from 1.4% in 1953 to 2.7% in 2013 (Figure 7.1). R&D spending rose quickly, peaking in 1964 on the back of rapidly rising federal R&D spending in support of the Apollo space project. Federal R&D spending as a share of GDP rose to 1.9% by 1964, but then was gradually scaled back as the Apollo project came to an end. Another surge in federal R&D spending occurred in the 1980s led by increased spending on energy R&D following the oil price shocks of the 1970s. This also tapered and federal R&D spending fell to 0.7-0.8% of GDP by 1995. It has remained at about this level since, with health research receiving a growing share of the total. R&D spending from industry, however, steadily rose from a low of 0.6% in 1953 to 1.8% by 2013, accounting for almost two-third of the total, while federal spending is slightly over one-fourth. Industry spending overtook federal spending in 1980 and has remained the dominant source of US R&D funding since. The category "other" includes spending by non-federal governments, universities and colleges, and other non-profits. It rose from negligible amounts to 0.22% of GDP.

Figure 7.1. Total R&D spending as a share of GPD, 1953-2013



Source: National Science Foundation (2016), Science and Engineering Indicators Report, Appendix Tables. www.nsf.gov/statistics/2016/nsb20161/#/downloads/report.

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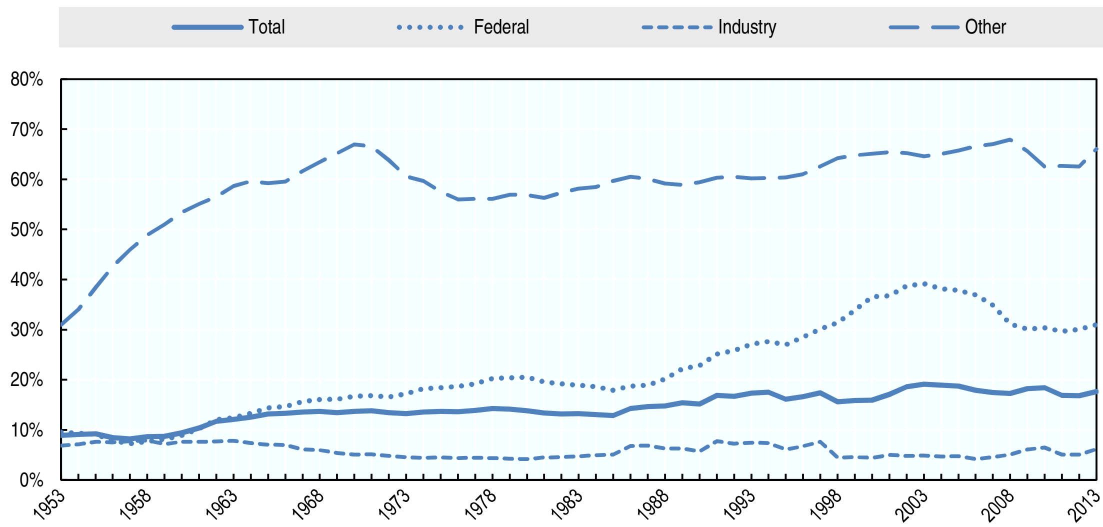
R&D is typically divided into three categories: basic research, applied research, and development (see the footnote to Table 7.2 for definitions of these terms). Basic research constitutes the work of fundamental discovery, with the purpose of enhancing our knowledge about the world. The share of basic research in total R&D spending has risen from 8.9% in 1953 to 17.6% in 2013 (Figure 7.2). Of the remaining R&D spending, in 2013 most went to development (62.4%), rather than applied research (20.0%). The rise in basic research as a share of R&D has been driven largely by the increasing specialisation of the Federal Government in basic research, and by the growth of the "other" category in total spending. While the Federal Government has long allocated more of its R&D to basic research than industry, the two were quite close through the 1950s. Since then the share of basic research in federal funding has risen to a peak of 39.2% in 2003, before falling to 31.0% in 2013. In contrast, the share of basic research in industry R&D has kept in the 4-8% interval over the period 1953-2013. The "other" category, which includes universities and colleges, has consistently devoted between 55-70% of R&D spending to basic research since 1961. As total funding in this category grew, it also contributed to the overall tilt towards basic research.

Figure 7.2. Basic research share of R&D expenditures, 1953-2013

Share of R&D that is basic research (%)



Source: National Science Foundation (2016), Science and Engineering Indicators Report, Appendix Tables. www.nsf.gov/statistics/2016/nsb20161/#/downloads/report.

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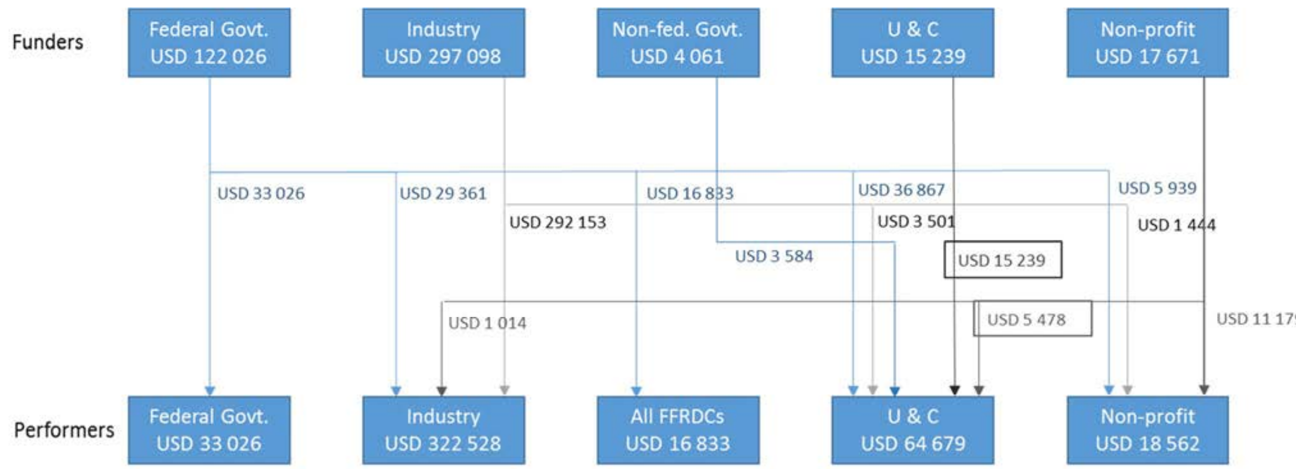
Figure 7.3 provides more detail on how R&D in the United States is currently funded and performed. Industry provides the largest share of funding for R&D. It also is the chief performer of R&D. Only a very small share of industry R&D funding is contracted to universities and colleges, or other non-profits, but the Federal Government allocates nearly a quarter of its own funds to industry performers. The Federal Government is also the largest source of funds for research performed by universities and colleges. Taken together, industry supplies 65% of R&D funds, but performs 71% of all R&D activities. Industry is also heavily skewed towards development, rather than basic or applied research. Development accounts for 78% of industry's R&D performance.

The Federal Government has a more balanced R&D profile, channelling approximately one third of its expenditures to basic research, one fourth to applied research, and the remainder to development. Because the Federal Government is one of the biggest funders of R&D, the USD 37.9 billion it spends on basic research accounts for 47.1% of all funding of basic research. As a performer of R&D, however, the Federal Government is more similar to industry, with development accounting for about half of federal R&D performance, and basic research accounting for 19%.

Universities and colleges supply just 3.3% of R&D funds, but are significant performers of research (14%). Universities and colleges also take the lead in basic research, performing half of all basic research. Other non-profit agencies contribute more to overall R&D spending, but have a much smaller footprint in terms of performing R&D. Universities and colleges, and other non-profits, are heavily tilted towards funding basic research.

Figure 7.3. R&D expenditures by sources of funds and performing sector in 2013



Figures in millions of current USD.

U&C: Universities and Colleges.

FFRDC: Federally-Funded Research and Development Center. FFRDCs are operated by industry, U&C, or non-profits.

Non-federal governments also performed USD 467 million of R&D (not shown in figure) with their own funds.

Source: National Science Foundation (2016), Science and Engineering Indicators Report, Appendix Tables. www.nsf.gov/statistics/2016/nsb20161/#/downloads/report.

Composition of federal R&D expenditures

For most of the post WWII period, defence has dominated R&D expenditures by the US government (Table 7.1). As late as 1990, at the end of the Cold War, defence R&D made up nearly two-thirds of total federal R&D spending. Since then, the share of non-defence R&D has risen, with most of the increase going to health research. Agriculture's share of total federal R&D declined in recent decades from 1.9% in 1980 to 1.4% in 2014.

Table 7.1. Federal R&D expenditures by function, 1960-2014

	Total spending	Defence	General science (NSF)	Atomic energy general science	Space	Energy	Trans-porta-tion	Health	Agri-culture	Natural res. and environ.	All other	Total non-defence
	Billion USD	% of total										
1960	42 056	81.1	0.8	2.5	4.5	2.2	1.1	3.8	1.5	0.9	1.7	18.9
1970	67 920	52.9	1.9	2.6	23.2	3.0	2.7	7.1	1.6	2.0	3.0	47.1
1980	69 506	48.4	2.8	1.1	14.1	10.9	2.8	12.2	1.9	3.1	2.6	51.6
1990	96 276	64.4	2.4	1.2	8.8	3.7	1.5	12.9	1.5	1.9	1.7	35.6
2000	90 766	55.5	3.3	3.0	7.3	1.7	1.9	21.5	1.7	2.3	1.7	44.5
2010	139 711	57.5	3.4	2.4	5.6	1.4	0.9	24.5	1.3	1.3	1.6	42.5
2014	121 490	53.7	4.0	3.1	8.2	1.8	1.0	23.4	1.4	1.5	1.9	46.3

Total spending given in constant 2009 USD where annual spending is deflated by the US GDP price deflator.

Source: Office of Management and Budget (2015) Historical Tables Table 9.8. www.whitehouse.gov/omb/budget/Historicals.

Table 7.2 breaks down the Federal Government's R&D expenditures by agency, character of work, and field of science for 2013. The Department of Defense (DOD) and the Department of Health and Human Services (DHHS) account for three-quarters of all federal R&D. DOD, which is heavily specialised in development, accounted for 50.0% of R&D expenditures on its own. In contrast, the DHHS (which includes the National Institutes of Health) is heavily specialised in basic and applied research in life sciences, and accounts for another 23.2% of federal R&D funding. In 2013, the USDA accounted for 1.6% of federal R&D obligations and primarily specialised in basic and applied research in the life sciences.

Table 7.2. Federal Government R&D obligations by selected agency, character of work and field of science, 2013

Million USD

	DOD	DHHS	DOE	NASA	NSF	USDA	Other	Total
Development	57 602	68	2 508	4 946	0	151	913	66 188
R&D plant	97	130	556	126	373	17	611	1 910
Applied	4 093	14 026	3 482	2 598	594	1 025	3 602	29 420
Basic	1 863	15 288	3 851	2 824	4 362	844	747	29 779
Total R&D	63 655	29 513	10 397	10 494	5 329	2 037	5 873	127 297
Basic and applied research by field of science								
Environmental science	301	362	320	1 202	922	33	901	4 041
Life science	713	24 599	390	321	666	1 462	1 179	29 330
Math and Computer Science	986	159	988	99	988	12	195	3 427
Physical science	739	154	2 696	1 365	872	97	359	6 282
Psychology	49	1 725	0	22	31	0	108	1 935
Social science	63	154	3	1	173	186	657	1 237
Other science	281	813	145	245	434	0	81	1 999
Engineering	2 823	1 348	2 793	2 167	870	79	868	10 948
Total basic and applied research	5 955	29 314	7 335	5 422	4 956	1 869	4 348	59 199

Definitions:

Research: the systematic study directed toward fuller scientific knowledge or understanding of the subject studied. Research is classified as either basic or applied research according to the objectives of the sponsoring agency.

Basic research: the objective of the sponsoring agency is to gain more complete knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind.

Applied research: the objective of the sponsoring agency is to gain knowledge or understanding necessary for determining the means by which a recognised need may be met.

Development: the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials devices systems or methods including design and development of prototypes and processes.

R&D Plant: investment in long-lived R&D physical assets such as facilities fixed equipment and land.

DOD = Department of Defense; DHHS = Department of Health & Human Services; DOE = Department of Energy; NASA = National Aeronautics & Space Administration; NSF = National Science Foundation; USDA = US Department of Agriculture.

Source: National Science Foundation (2016), *Science and Engineering Indicators Report*, Appendix Tables. www.nsf.gov/statistics/2016/nsb20161/#/downloads/report.

The US food and agricultural R&D system: Actors and funding

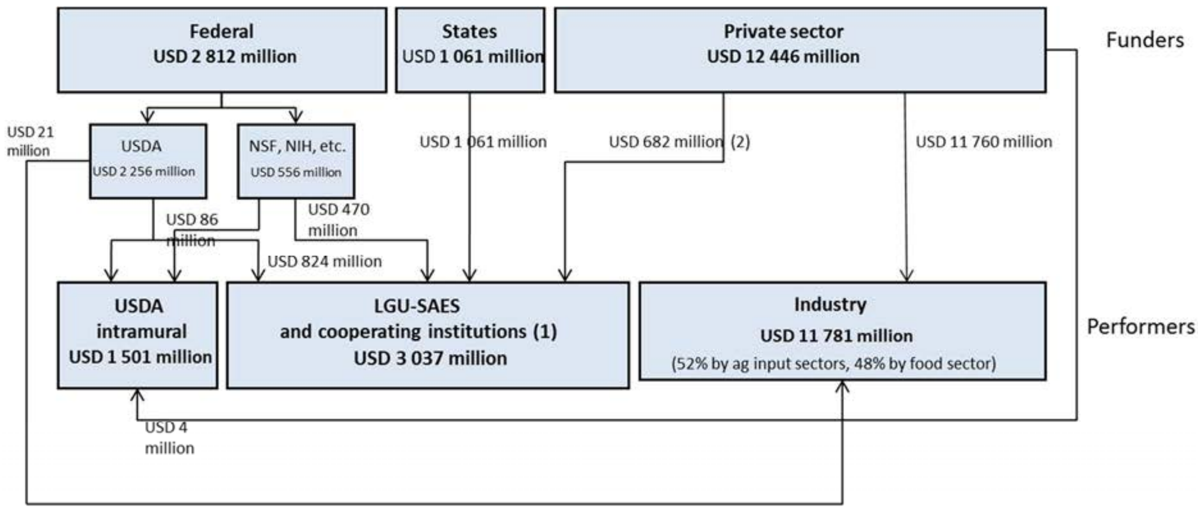
Over the past 150 years the original federal-state cooperative enterprise providing agricultural research, extension and education services evolved to accommodate changes in the broader innovation systems affecting agriculture. One important development is the increasing research capacities in the private business sector to provide innovations for farms. While formal research by farms remains negligible, manufacturing firms, seed companies and other private R&D service providers invest significant resources in research to develop new technologies for use in agriculture. Another significant development is the emergence of stronger linkages between agricultural sciences and other fields, especially biological sciences and information technologies. This has expanded the set of institutions funding and preforming research relevant to agriculture. How these developments have affected the organisation and function of the US food and agricultural R&D system are discussed below.

Funders and performers of food and agricultural research

In 2013 (the latest year for which comprehensive estimates are available), federal, state, and private institutions funded and performed approximately USD 16.3 billion worth of R&D for food and agriculture (Figure 7.4). Of this total, the majority was funded and performed by the private sector. The Federal Government, through the USDA and other federal agencies, funded approximately USD 2.8 billion of R&D (or 17% of R&D for food and agriculture). Of this total, about USD 1.5 billion worth of federally-funded research was performed by USDA intramural research agencies. Land Grant Universities (LGUs), State Agricultural Experiment Stations (SAES), and other cooperating institutions received USD 3.1 billion from all sources, including USD 1.3 billion in federal monies, for agricultural R&D. About two-thirds of the federal support for LGUs was channelled through the USDA and the rest from other federal agencies. These state institutions received another USD 1.1 billion from State governments and USD 0.7 billion from non-government sources for research. Non-government sources include contributions from commodity groups (check-off funds), private companies, non-profit foundations, and earnings from licensing fees and product sales. Research performed at USDA, LGU-SAES, and cooperating institutions is mostly oriented toward agriculture, but also includes research on forestry, natural resources, food and nutrition, economics and statistics, and rural development.

Food and agricultural research performed by private industry is financed almost entirely by for-profit companies, and include firms from several industrial sectors. Of the estimated USD 11.8 billion in R&D performed by these firms in 2013, just under half was by the food manufacturing sector (companies that process raw agricultural commodities into food products). Research by these firms was heavily oriented to new product development or manufacturing process improvements. Relatively little of the R&D performed by the food manufacturing sector was for agricultural technology. The other part of private R&D was to develop improved inputs for use on farms and was performed by crop seed and livestock genetic companies as well as a range of manufacturing industries (chemical, machinery, biotechnology, and pharmaceutical). In addition to the for-profit sector, some agricultural research is conducted by private, non-profit institutes funded primarily through charitable or government grants (these form a very small part of the system in terms of funds involved and are not shown in Figure 7.4).

Figure 7.4. Funders and performers of food and agricultural research in 2013



1. LGU-SAES and cooperating institutions: The 1862 and 1890 Land Grant Universities and State Agricultural Experiment Stations. Cooperating Institutions include Veterinary Schools, Forestry Schools, and other US colleges and universities receiving agricultural research funding from the USDA.

2. Private sector contributions to LGU-SAES (USD 682 million) consist of (i) research grants and contracts from private companies (ii) research grants from farm commodity groups, philanthropic foundations, individuals and other organisations, and (iii) revenue and fees from the sale of products, services, and technology licenses.

Source: USDA Economic Research Service.

Long-term trends in food and agricultural R&D spending

In recent decades, food and agricultural R&D performed by the private sector has grown faster and has become significantly larger than food and agricultural R&D spending by public institutions (Figure 7.5). Private food and agriculture R&D nearly doubled between 2003 and 2013, from around USD 6 billion per year USD 11.8 billion in 2013 (in constant 2013 USD). Private R&D spending by food manufacturing firms and agricultural input industries increased in tandem.

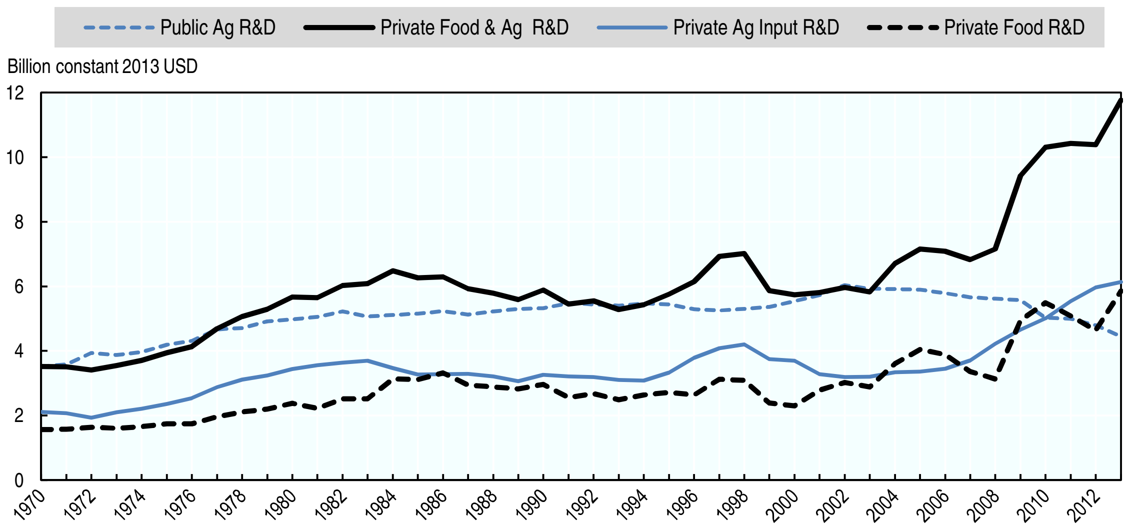
Public agricultural R&D, meanwhile, declined in real terms. For agricultural-related research alone, which historically the public sector has dominated, by 2011 the private had overtaken the public sector. Some of the key drivers of the growth of private investment in food and agricultural research have been: 1) advances in science that have opened up new opportunities for commercial technology development, 2) stronger intellectual property rights over biological innovations, 3) expansion of national and global markets for new food products and agricultural inputs, and 4) new regulatory requirements over new product introductions (Fuglie et al., 2011).

Trends in public sector research have been driven particularly by expenditures by state institutions, where two thirds of the public sector research was performed in 2013. State-level public agricultural research expenditures rose in real terms until about 1990, with funding increases coming from many sources, including appropriations from state legislatures. Since 1991, however, total agricultural research appropriations by all State governments combined has fallen in real terms. Decline in state funding was initially offset with increases in funding from other sources, including non-USDA federal agencies and industry (Schimmelpfennig and Heisey, 2009). However, total agricultural research expenditures by state institutions began to fall in 2002. USDA intramural research expenditures have fluctuated over time and also drifted downwards in real terms after 2002.

As a result of lower public sector expenditure on agricultural R&D in the United States combined with higher capacity in emerging economies in particular, the US share of global spending on public agricultural research fell from 21% to 13% between 1960 and 2009 (Pardey et al., 2013).

In purchasing-power-parity dollars, US spending on public agricultural research has fallen substantially below spending by China and Western Europe (Figure 7.6).

Figure 7.5. Public and private spending on food and agricultural R&D, 1970-2013

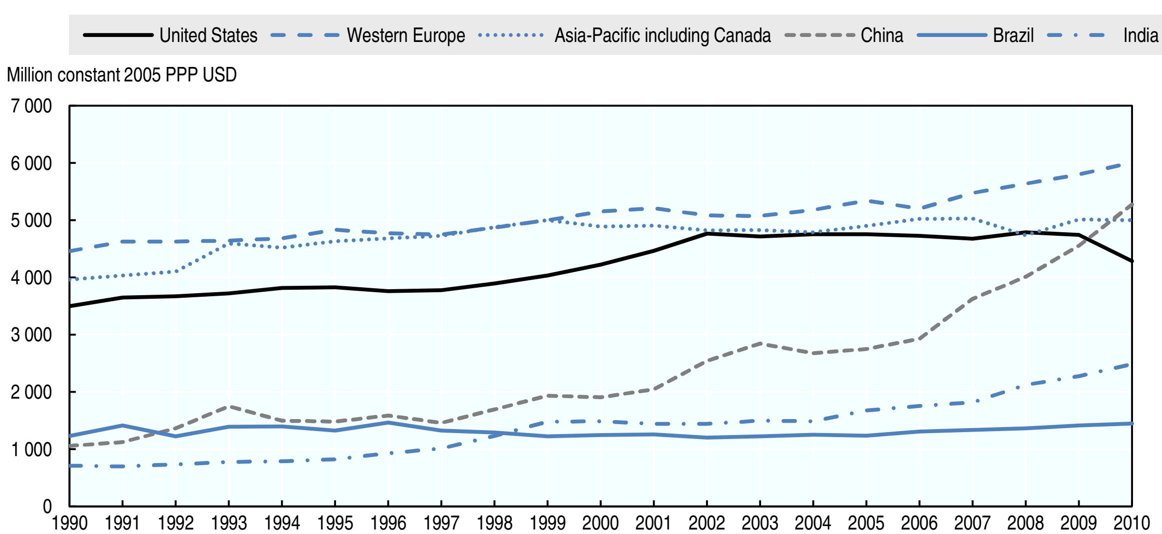


Annual spending on research is adjusted for inflation by a research price index constructed by ERS.

Source: USDA (2015a), Economic Research Service. www.ers.usda.gov/data-products/agricultural-research-funding-in-the-public-and-private-sectors.aspx.

StatLink http://dx.doi.org/10.1787/888933408944

Figure 7.6. Expenditures for public agricultural research by the United States and other major countries and regions, 1990-2010

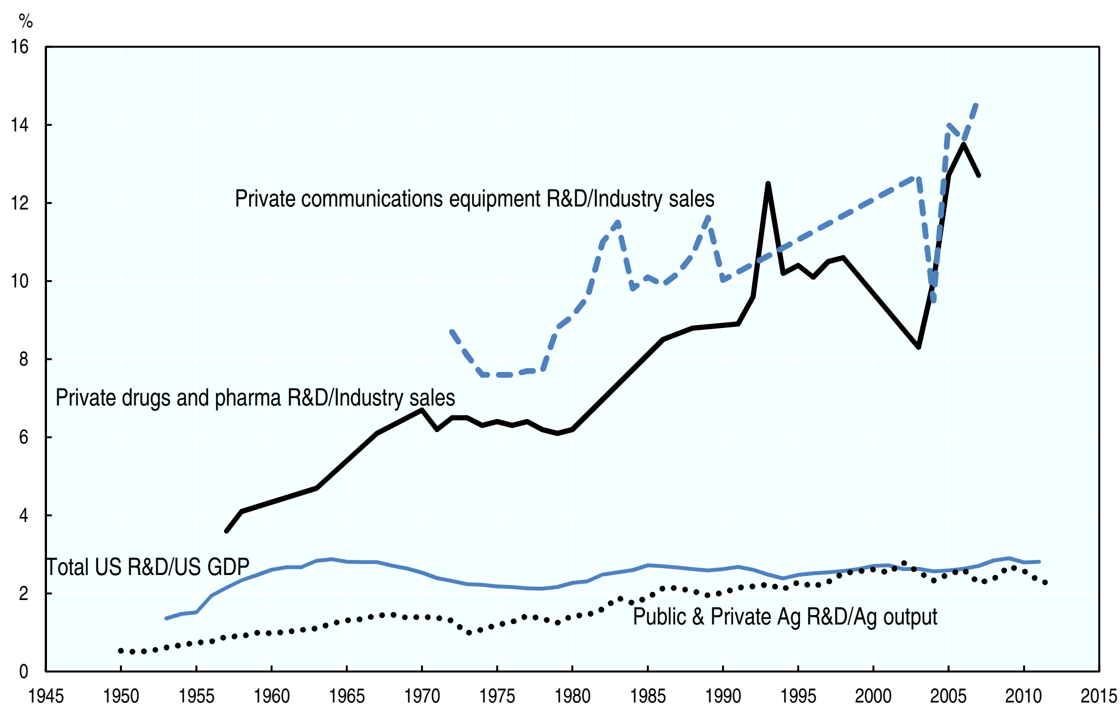


Source: Agricultural Science and Technology Indicators (2015) (ASTI) www.asti.cgiar.org/data and USDA (2015a), Economic Research Service. www.ers.usda.gov/data-products/agricultural-research-funding-in-the-public-and-private-sectors.aspx.

StatLink http://dx.doi.org/10.1787/888933408958

Despite the recent growth in private R&D, total funding for agricultural R&D in the United States is not exceptional when compared with the size of the sector. As a share of the gross value of output (the research intensity), total public and private R&D spending for agriculture was equivalent to 2.32% the value of farm sales in 2011, compared with 2.57% for the US economy as a whole (Figure 7.7), This is far below private R&D levels in high-technology sectors like information technology and pharmaceuticals, where research intensity exceed 15%. The food manufacturing sector is even lower, with business R&D is less than 1% of gross sales (not shown in the figure). Although data are not strictly comparable in their coverage of activities, it seems that the share of public expenditure on agriculture R&D in agricultural value-added in the United States was close to that in Brazil and Australia, but lower than in Canada and the Netherlands (OECD, 2015b). It would be useful to improve data comparability at the international level to be able to better evaluate respective efforts.

Figure 7.7. Research intensities for agriculture and selected sectors of the US economy, 1940-2013



Source: National Science Foundation (2014), www.nsf.gov/statistics/seind14/index.cfm/etc/sitemap.htm, except for agriculture, which is from USDA (2015b), Economic Research Service, www.nsf.gov/statistics/seind14/index.cfm/etc/sitemap.htm.

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Public and private agricultural R&D: Crowding out or complementary?

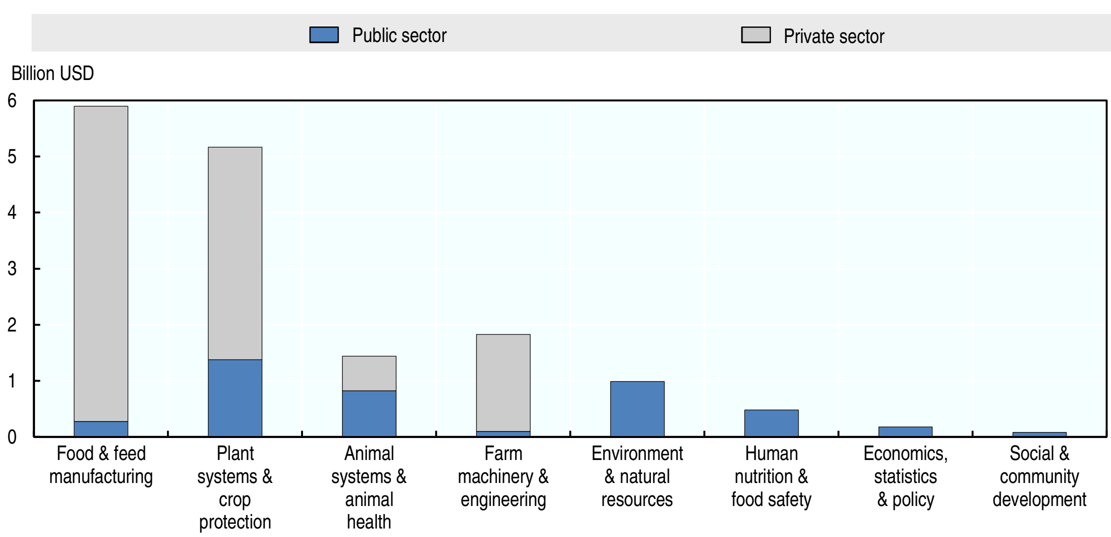
The market failure argument provides an economic rationale for the public sector to fund basic and applied R&D. However, if the public sector competes directly with private innovators in the provision of new technologies for businesses or consumers, it could crowd out private R&D. On the other hand, by focusing on areas where there is thought to be a large gap between social and private returns to research — in other words, on areas that have a large public-good component — public R&D could complement private R&D.

Economic studies have tested the crowding-out hypothesis for agricultural research and have generally found that US public and private agricultural research are complementary. These studies find evidence that public R&D stimulates greater private R&D by creating opportunities for businesses to develop and commercialise new products and processes for economic growth. Each dollar spent on public food and agricultural research appears to stimulate about USD 0.70 in additional private R&D spending (Fuglie and Toole, 2014). One implication of the complementarity between public and private research is that continued robust public investments in science may be necessary to prevent private agricultural R&D spending from eventually tapering off.

Comparisons of public and private agricultural R&D resource allocations across topic areas help to illustrate this complementarity (Figure 7.8). Private R&D dominates food manufacturing and farm machinery and makes major investments in plant systems, while public R&D addresses a broad set of socially important issues like environment and natural resources, food nutrition and safety, economics and statistics, and community development, where private R&D is low due to the significant public goods dimension of these kinds of research. It is difficult for private companies to justify research investments such as those exploring human nutrient requirements, soil and water resources conservation, and other important public goods because of the difficulty of capturing a return on investment in these activities.

Both the public and private sectors make significant investments in plant and animal systems. A closer inspection of the specific kinds of research and fields of science emphasised by each sector reveals further evidence of complementarity. Much of the private R&D for plant and animal systems is oriented toward the discovery and commercialisation of new agricultural pesticides, veterinary pharmaceuticals, and introducing genetically-engineered (GE) traits into crop cultivars, areas with little public-sector counterpart. Even in crop and livestock breeding, public and private R&D appears to be concentrated on different fields of science, with public scientists concentrated in more basic biological disciplines and private sector scientists in more applied fields (Figure 7.9) Public plant breeders, for example, focus more on upstream research like developing new general-purpose plant breeding tools and enhancing germplasm (parent lines used to breed commercial cultivars), whereas private plant breeders are heavily concentrated on cultivar development.

Figure 7.8. Composition of public and private food and agricultural R&D by sub-sector in 2013



Sources: Public R&D spending from USDA (2015c), National Institute for Food and Agriculture https://nifa.usda.gov/data; private R&D spending is from Fuglie (2016, forthcoming).

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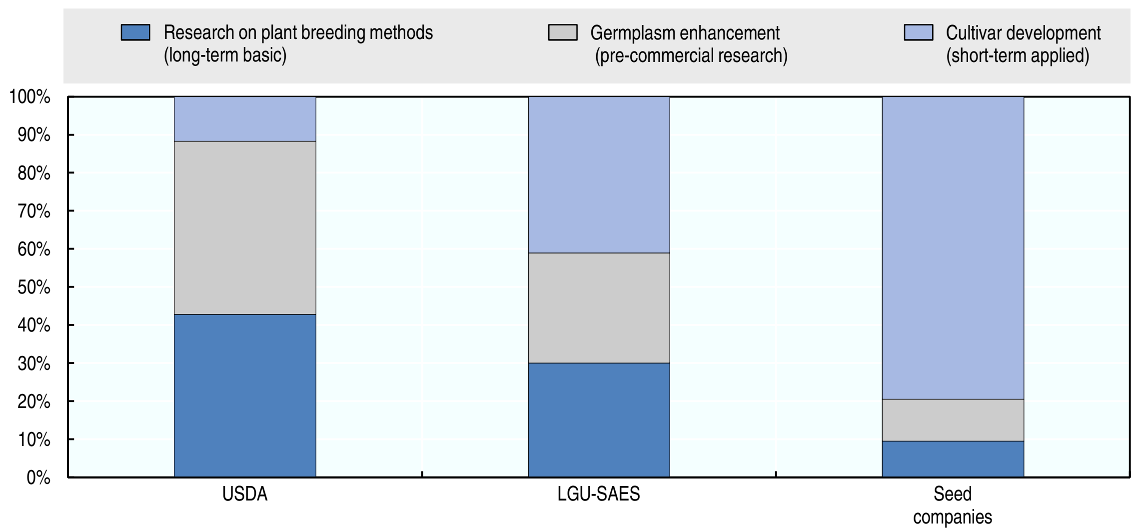
Figure 7.9. Allocation of public and private plant breeding among basic, pre-commercial and applied research activities, 1994

Share of breeders' time devoted to activity



Source: Frey (1996), *National Plant Breeding Study*, Special Report 98. http://nifa.usda.gov/sites/default/files/resource/National%20Plant%20Breeding%20Study-1.pdf.

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Governance of the R&D System

In the US Federal Government, there is no single science agency that sets research priorities. Rather, there is a highly decentralised process by which priorities and budgets for R&D are established in the several departments and agencies responsible for research (Ruttan, 2001). It involves these departments and agencies, the authorisation and appropriation committees of Congress, and at the level of the Executive Office of the President, the Office of Budget and Management, the Office of Science and Technology Policy (OSTP), and the National Science and Technology Council (NSTC).

The NSTC is responsible for coordinating science and technology policy across the diverse entities that make up the federal R&D enterprise. Chaired by the US President, the NSTC membership includes the Director of OSTP, cabinet secretaries, heads of agencies with significant science and technology responsibilities, and other officials. The work of the NSTC is currently organised around five committees, each with sub committees and interagency working groups that coordination work on specific areas of research. The USDA is represented on several of the coordination bodies.

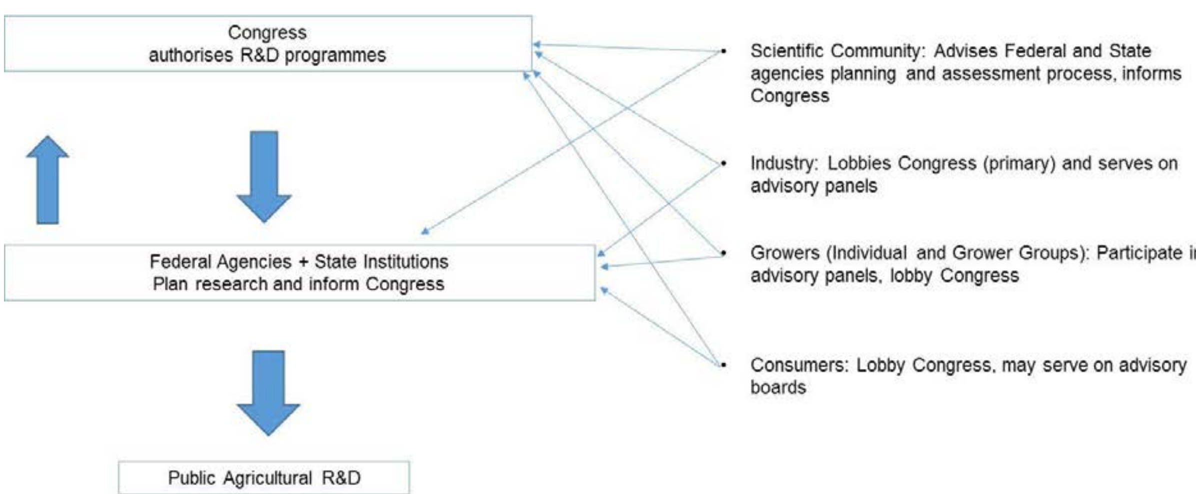
The Congress is responsible for the legislation that enables federal programmes and agencies, and determines their funding levels. In 1993, the Congress passed the Government Performance and Results Act (GPRA), which established performance guidelines for all federal agencies. Under GPRA, departments and agencies are required to develop five-year strategic plans with measurable, result-oriented goals and annual performance reports that review the agency's success or failure in meeting its targeted goals.

USDA research planning and stakeholder input

Within the USDA, agricultural research is conducted among various mission areas and by multiple agencies. The Agricultural Research Service (ARS) is the USDA's primary intramural research performer. The National Institute for Food and Agriculture (NIFA) is responsible for USDA's extramural programmes that fund research, extension and education activities at universities and in the private sector. The National Agricultural Statistic Services (NASS) and the Economic Research Service (ERS) are responsible for collecting agricultural statistics and providing analysis for food, agricultural and natural resource policy. These four agencies make up the USDA's Research, Education and Extension (REE) mission area. Additional research is conducted outside REE. Among that, research related to forests and grasslands conducted by the US Forest Service is of particular importance. (The Forest Service operates within the USDA's Natural Resource and Environment mission area.)

The Office of Chief Scientist (OCS) is responsible for coordinating agricultural research within the USDA-REE agencies and with other federal research agencies. Research priorities are established with significant stakeholder inputs (Figure 7.10). Stakeholders inform and influence these priorities not only through lobbying activities, but also through formal mechanisms such as advice and recommendations from the National Agricultural Research, Extension, Education, and Economics Advisory Board (NAREEEAB). The twenty-five NAREEEAB members each represent a specific stakeholder category, such as a national nutritional science society, national farm organisations, commodity groups, agricultural universities, and industry associations.

Figure 7.10. Stakeholders and governance structure for setting agricultural research policy



In addition, each major programme area within REE research agencies engages stakeholders when planning their programme activities. For example, the ARS currently organises its research into 17 National Programmes. To establish their research agendas, each National Program consults stakeholder groups to help identify key research needs and opportunities. The National Programmes provide an important mechanism for coordinating research within the broader US agricultural innovation system. University partners with similar interests are closely engaged in order to coordinate research between federal and state institutions. The private sector (commercial firms and non-profit organisations) is also represented in these planning discussions.

Another important source of stakeholder inputs is external scientific advice from the National Academies of Sciences, Engineering and Medicine. The National Academies are self-governing, private, non-profit organisations charged by Congress to provide independent advice to the Federal Government. They draw upon pre-eminent scientific expertise from colleges and universities to author their reports. In 2009, the National Academy of Science released a study, *A New Biology for the 21st Century*, which called for stronger integration of new advances in fundamental biological sciences into federal science agencies to address pressing societal needs, especially for food, environment, energy and health. The National Research Council Board on Agriculture and Natural Resources (an operational arm of the National Academies) also periodically releases studies on aspects of the federal agricultural research enterprise. In 2014, for example, it published a critique of the USDA's principal competitive research grants programme, the Agriculture and Food Research Initiative.

To assist in coordination and planning, the USDA maintains a detailed database of all agricultural research projects funded and carried out by federal and state partners in the US agricultural research system. The *Current Research Information System* (CRIS) has been in place since 1966 to track research resources by subject matter, performer, source and amount of funding, and outcomes. It was activated in 1969. USDA-funded projects dealing with human nutrition are also reported in the *Human Nutrition and Information Management* (HNRIM) database maintained by the National Institutes of Health (part of DHHS). The USDA, DHHS, and other federal agencies funding nutrition research all report to this database. These searchable on-line databases and their annual reporting summaries are valuable tools for federal and state science managers and scientists. In addition, CRIS has been a critical resource for retrospective assessments of the economic impacts of agricultural research. Using data that measure research resource flows to specific subject areas and specific geographic areas, and linking them to subsequent changes in farm productivity, economists have been able to conduct cost-benefit analysis of public investments in agricultural research. A summary of the findings from these studies is given in Chapter 7.

The USDA Research, Education and Extension Action Plan

The current USDA strategic plan for agricultural research (the Research, Education, and Economics Action Plan) identifies seven priority goals:

- Sustainable intensification of agricultural production
- Responding to climate and energy needs
- Sustainable use of natural resources
- Nutrition and childhood obesity
- Food safety
- Education and science literacy
- Rural prosperity and rural-urban interdependence.

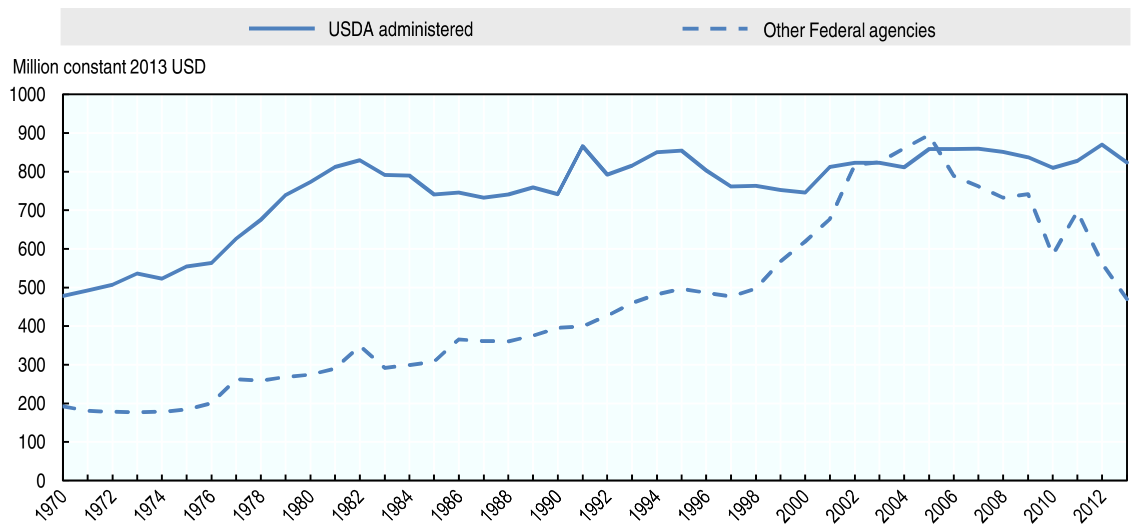
Each of these seven goals has strategies and planned actions that designate the specific USDA agencies responsible for implementing the actions (For an update of the REE Action Plan, see USDA, 2014b).

Co-ordination among USDA and other federal agencies in food and agricultural R&D

Increased opportunities to exploit advances in fundamental biological sciences for food and agriculture, expanded uses of agricultural commodities for new industries like biofuel, implications of food and agricultural systems for human nutrition, food safety, and the environment, issues of biosafety and national and homeland security, all serve to draw several federal science agencies into food and agricultural research. Funding of agricultural research by non-USDA federal agencies grew rapidly in the 1980s and 1990s, and briefly surpassed extramural research funding by the USDA, before dropping sharply after 2007 (Figure 7.11). The DHHS (primarily through the National

Institutes of Health), the National Science Foundation, the Department of Energy, the Department of Defense, and USAID were all important sources of this funding.

Figure 7.11. Extramural funding for agricultural research by the USDA and other federal agencies, 1970-2013



Annual spending is adjusted for inflation using a "cost of research" price index from ERS.

Source: USDA (2014a), Economic Research Service. www.ers.usda.gov/data-products/agricultural-research-funding-in-the-public-and-private-sectors.aspx.

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NSTC sub-committees and interagency working groups, as well as federal science project databases like HNRIM for human nutrition research, are important mechanisms for coordinating among these diverse players. Research coordinating bodies are often established around key federal research priorities, such as the special initiatives presented in Box 7.2.

Box 7.2. Coordinating research across federal agencies: Examples involving agriculture

Plant Genomics. To develop and exploit fundamental advances in biological sciences for plant genomics, in 1997 the NSTC formed an Inter-Agency Working Group on Plant Genomics (IWGPG). With representatives from the USDA, NSF, DHHS, DOE, USAID, other federal offices, and inputs from stakeholder groups, the IWGPG has developed a series of five-year plans and reported on the achievements of the National Plant Genome Initiative. The plan outlines the priority areas for investing federal resources and describes the commitments of each agency toward these priorities. The USDA has major responsibilities for the conservation and characterisation of crop genetic resources and broadening biodiversity in advanced breeding material for use in commercial breeding programmes.

Climate Change. The United States Global Change Research Program (USGCRP) began as a presidential initiative in 1989 and was mandated by the Congress in 1990. The USGCRP coordinates climate change research across thirteen federal agencies and is steered by NSTC Subcommittee on Global Change Research. Under the current USGCRP ten-year strategic plan (2012-21), USDA contributions include assessing the impacts of climate change on agriculture, developing greenhouse gas inventories, developing new production technologies and practices that are drought tolerant and resilient, and developing and deploying decision-support tools for agricultural producers and policy-makers.

Human Nutrition. Improving nutrition could be one of the most cost-effective ways to address morbidity, mortality and socioeconomic burdens associated with chronic diseases and disorders. In the 1970s, mounting evidence of hunger and malnutrition in the United States led to increased funding for human nutrition research by the Federal Government. Since 1983, human nutrition research has been coordinated by the Interagency Committee on Human Nutrition Research (ICHNR). The ICHNR is co-chaired by the USDA and the DHHS and includes representatives from eight other federal departments and agencies as well as the White House Office of Science and Technology Policy. The ICHRN has been instrumental in strengthening procedures for the monitoring of the nutritional status of the US population and improving the Dietary Guidelines for Americans. The Guidelines, issued by the Federal

Government every five years, provide recommendations for a nutritionally balanced diet developed from a review of relevant scientific evidence. The Guidelines are widely used by government agencies, for all federal dietary guidance, and food assistance programmes (Toole and Kuchler, 2015), as well as by consumers and diet-related industries (USDA, 2015). The ICHRN also put in place the HNRIM system to record and track all nutrition research projects performed or funded by the Federal Government. ICHRN is presently developing a new five-year strategic plan for federal nutrition research (ICHRN, 2016).

Bioenergy. Advancing bioenergy technologies has been an important objective for both the USDA and the DOE. Coordination of bioenergy-related R&D activities across federal agencies is achieved through Biomass Research and Development Board (BRDB), rather than the NSTC. The BRDB was mandated by Congress in the Biomass Research and Development Act of 2000 and subsequent legislation. Board members include representatives from the USDA, DOE, Department of Transportation, the OSTP, and other federal agencies. Stakeholder input is provided by the BRDB Technical Advisory Committee, which draws its members from industry, academia, non-profit organisations, and local governments. The USDA and DOE collaborate on the Biomass Research and Developing Initiative, a competitive research grant programme to promote feedstock development, biofuel and bio-based product development, and analysis on energy and environmental impacts.

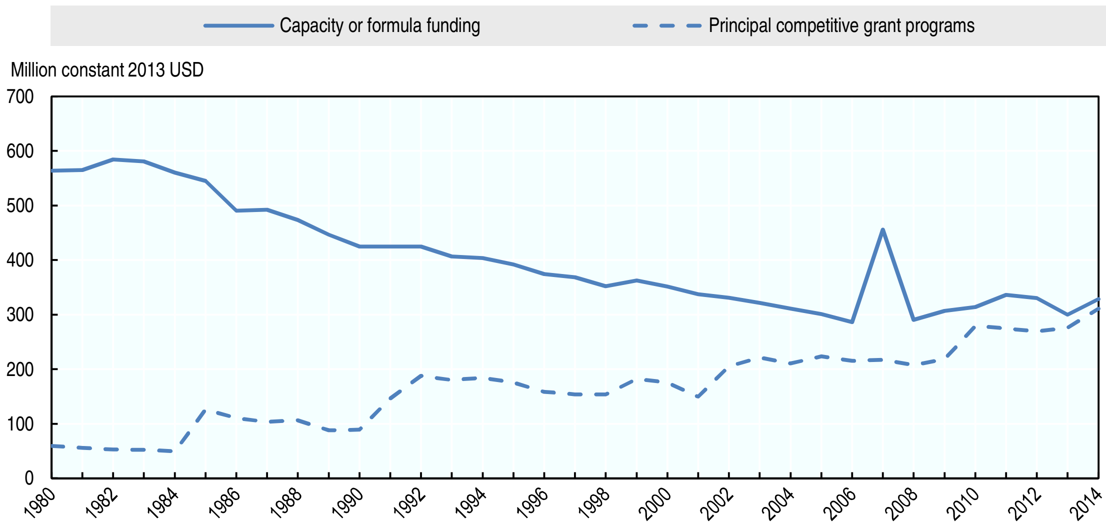
USDA funding mechanisms for extramural research

In the early years of the federal-state agricultural R&D system, the USDA supported Land Grant University-State Agricultural Experiment Stations (LGU-SAES) through a formula funding system (also called capacity research grants) where states received a fixed share of available federal funds. State governments were required to match the federal contribution. The matching requirement helped to mobilise farmer support for and involvement in their state agricultural research system (Huffman and Evenson, 1993). The federal contribution also serves as partial compensation for the fact that research performed by state institutions produces significant 'spillover' benefits to other states (Ruttan, 1982). Decisions regarding resource allocation of capacity research grants to LGU-SAES are largely left to the states, and much of this effort focused on problems and needs of the individual state or region.

In recent decades, the USDA has given greater emphasis to competitive funding mechanisms for research support at LGU-SAES. Competitive project funding programmes shift decision-making on resource allocation from state institutions to the federal funding agency. Centralised, competitive funding can direct funding to research that has greater national scope and to scientists and institutions thought to be best able to carry it out. Competitive funding programmes are also open to universities and other institutions outside the LGU-SAES system. However, competitive funding programmes also entail significantly higher transactions costs (scientist and research administration resources devoted to obtaining funding and managing projects) compared with capacity funding (Huffman and Evenson, 2006a; Prager et al., 2014). Congress may determine funding priorities for some competitive programmes, though scientists generally determine the institution performing the research.

The US Congress authorised the USDA's first competitive grants programme for agricultural research in 1977, and expanded it in 1990 when it established the National Research Initiative (NRI) Competitive Grants Program. In 2009, the NRI was replaced by the Agriculture and Food Research Initiative (AFRI). Meanwhile, funds allocated to capacity grants declined. By 2010, USDA extramural support for agricultural research was almost evenly split between capacity and competitive grants (Figure 7.12). However, empirical studies have not been able to find clear superiority of one funding mechanism over another. Huffman and Evenson (2006a) found that states receiving a higher proportion of agricultural research funds through institutional support (capacity grants and state appropriations) achieved higher productivity growth than states that relied more heavily on project support (competitive grants, contracts and other forms of research support). Prager et al. (2014) found that despite individual scientist's devoting significantly more time to research project administration and management, their per capita research output remained about the same.

Figure 7.12. Budgets for USDA capacity and competitive extramural research, 1980-2014



Principal competitive grant programmes include the National Research Initiative (1991-2007) and the Agriculture and Food Research Initiative (2008-present).

Capacity or formula funding include Hatch Act funds allocated to the State Agricultural Experiment Stations (SAES); Evans-Allen funds allocated to 1890 (historically black) agricultural universities; McIntire-Stennis funds for forestry research; and Animal Health funds.

Not included in the figure are Congressionally-earmarked and other grant programmes targeting specific areas such as sustainability, organic agriculture, bioenergy, and specialty crops. Earmarked funds are non-competitive. Some, but not all, area-targeted research programmes are also allocated competitively. The spike in capacity funding in 2007 reflects a one-time transfer of funds from a non-competitive programme to the Hatch programme.

Source: USDA (2015d), Office of Budget and Program Analysis. www.obpa.usda.gov/budsum/budget_summary.html.

StatLink http://dx.doi.org/10.1787/888933409000

Evaluation procedures of research in government agencies

Governance also ensures that policy outcomes and impacts are evaluated against government priorities. Solid and transparent evaluation procedures are needed to improve the performance of the research and innovation system. The main tool for evaluating all federal agencies, including research agencies, is the Government Performance and Results Act. USDA is also a partner in the STAR METRICS consortium (Science and Technology for America's Reinvestment: Measuring the EffecT of Research on Innovation, Competitiveness and Science) between US federal science agencies and research institutions to document the return on investment, research impact, and social outcomes of federally funded research and development.

ARS programme performance against targets is monitored annually. Each National Program Team (NPT) prepares an annual report featuring the National Program major accomplishments. Data for annual monitoring are provided by the research projects.

At the end of each national programme's five-year cycle, the NPT prepares an accomplishment report, which is discussed with an external review panel, who in turn prepare the National Program evaluation report. Criteria used to select stakeholders in external review panel are not known (Jolly et al., 2016).

The purpose of impact evaluation is to demonstrate accountability to partners and the Federal Government regarding the benefits of ARS-funded research systems programmes, through monitoring and evaluation. Annual monitoring and end of funding review provide information for the new funding cycle and accomplishments at the level of ARS. Evaluation results are posted on the agency's website.

There are no public guidelines for evaluation design, methods and methodology, but some harmonisation in the format of National Program accomplishment reports. An Action Plan Scorecard measures outputs and outcomes, using narratives from the reports to provide evidence for impact. Methodologies include mixed review panels (academics, stakeholders and government). Measurement of achievement includes programme-based quantitative targets; science quality, client satisfaction, and diffusion of scientific output beyond academia.

In addition to this formal evaluation, researchers in government agencies (e.g. ERS) and universities have produced numerous studies evaluating the impact of R&D and innovation on the economic and environmental performance of the sector. Using the long time series available in the United States, studies report high rates of return to agricultural research (see section 7.6 for some examples).

Fostering innovation

Special features of agriculture mean that the extent and nature of the market failures to invest in technology development and dissemination differ from elsewhere in the economy. Because of the atomistic structure of production (comprised of relatively small firms producing multiple homogeneous products), few farms are willing or able to investment in formal R&D for their farms. Furthermore, because of the biological nature of agriculture, improved crop seed and animal breeds are self-replicating. This complicates the ability of innovators to protect intellectual property. In addition, many agricultural technologies tend to be geographically specific, meaning that they do not transfer directly to other locations with different soil types, weather patterns, or topography. These features imply that unique policies to foster innovation in agriculture are required.

While farms themselves do little formal R&D, specialised firms do invest in R&D for the agricultural sector. Manufacturing firms in the machinery, chemical and pharmaceutical sectors, crop and animal breeding companies, and biotechnology companies conduct R&D to develop improved inputs for sale to farmers. The growing R&D capacity of the private sector for agriculture implies that public agricultural R&D is increasingly focused on more fundamental science and pre-commercial research activities. But transfer of scientific advances to commercial application is also confronted with market failure. This section describes policies designed to strengthen incentives for businesses to invest in agricultural research and new institution structures that have developed to strengthen linkages between public science and private R&D.

While manufacturers of agricultural inputs (seeds, chemicals, machinery, veterinary pharmaceuticals, etc.) market their innovations to farmers, the public sector has long maintained an agricultural extension system to extend new knowledge and management practices to farms and rural households. The US public agricultural extension system is a unique federal-state-local government partnership with a broad mandate not only to foster agricultural innovations but which also includes rural youth and community development

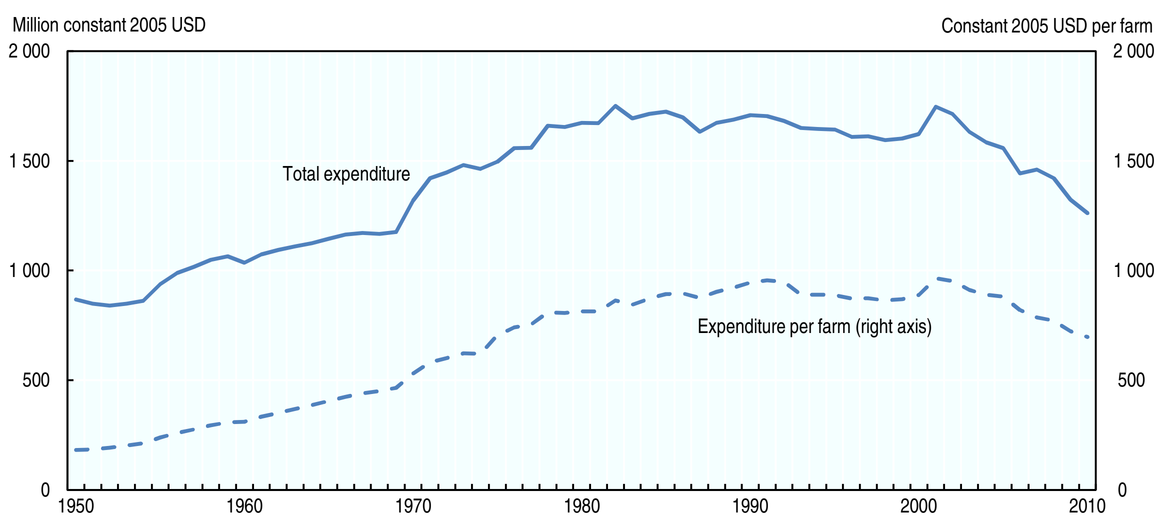
Agricultural extension

Throughout its history cooperative extension has been a unique partnership between federal, state and local governments to promote agriculture, conservation, youth education, rural development, health and nutrition. In its early decades, the Federal Government, through the USDA, provided 40-50% of the total funding for cooperative extension, with state and local governments providing the rest. The federal share of funding for cooperative extension has gradually declined over time, and presently makes up 20-25% of total extension funding. In constant 2005 dollars, total public expenditures for cooperative extension peaked in 1982 at just over USD 2 billion and by 2010 had declined to under USD 1.5 billion (Figure 7.13).

While the USDA establishes broad programme priorities for the funds it provides and state matching funds, state and local partners play a major role in defining priorities for cooperative extension. States report how cooperative extension funds are allocated across Knowledge Areas to the USDA. While priorities across individual states and associated territories differ, at the national level there is a significant degree of cohesion in budget allocation across major programme areas, regardless of funding source. While originally cooperative extension had a strong agricultural technology transfer focus, in its present form it addresses a wide range of rural and non-rural community needs. Only about one-fourth of extension expenditures are to support crop and animal farming ("plant systems" and "animal systems" in Figure 7.14). Education activities for families, youth and communities, most notably the youth-oriented 4-H program, accounts for 30% of extension resources. Human nutrition and health education made up another 17% of extension funding (Figure 7.14).

By 2010 there were just over 12 000 full-time staff employed in the US cooperative extension system, down from over 16 000 at the peak funding period of the early 1980s (Figure 7.15). A large part of the reduction came about by consolidating programmes in rural counties and reducing the number of county agents (generalists responsible for administering extension programmes within counties). The number of extension staff with specialised expertise serving regional or state-wide programmes has remained at approximately 4 000 nation-wide since the 1980s.

Figure 7.13. Public agricultural extension expenditures, 1950-2010



Nominal expenditures adjusted for inflation by a cost of research price index.

Figures include contributions from federal, state and local governments.

Source: Extension expenditures from Alston et al. (2010) with updates from USDA-National Institute for Food and Agriculture (b); Number of farms from USDA (2015e), National Agricultural Statistical Service. https://nifa.usda.gov/data; Cost-of-research price index from USDA-Economic Research Service.

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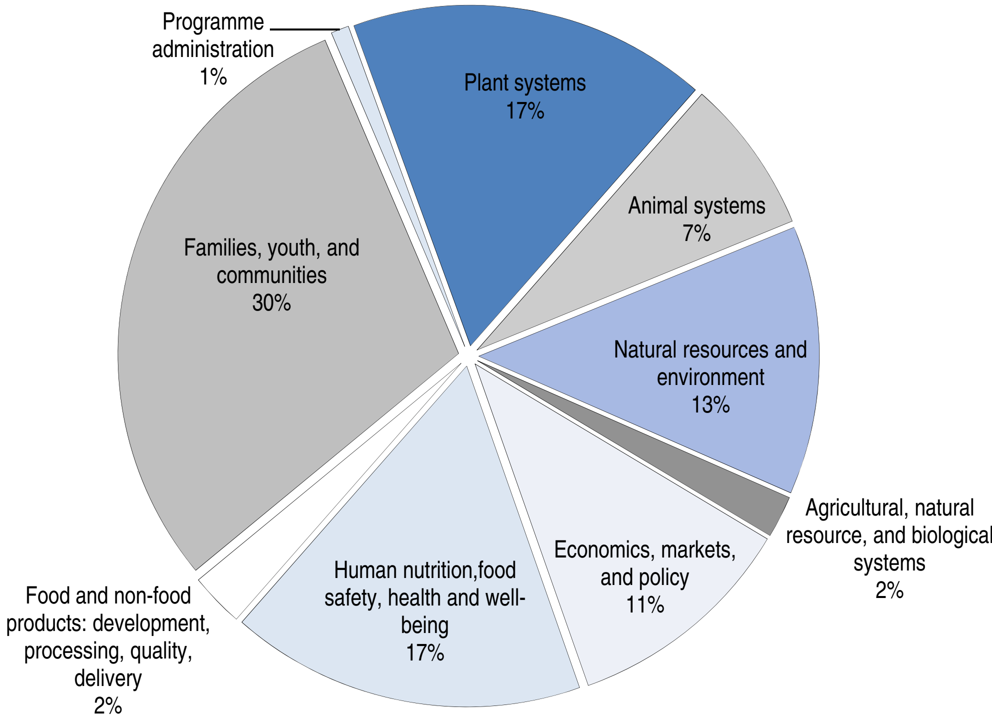
Figure 7.14. Allocation of agricultural extension spending by programme area in 2012



Source: USDA (2016a),National Institute for Food and Agriculture, Research, Education, and Economics Information System, US Department of Agriculture, Washington, DC. https://nifa.usda.gov/data.

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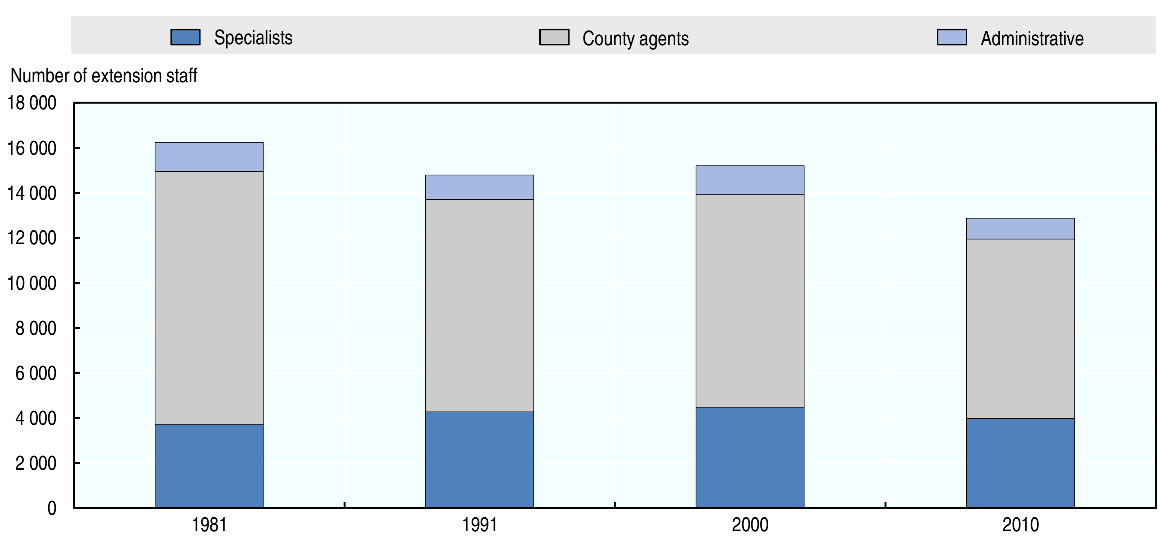
Figure 7.15. Composition of agricultural extension staff in 1981, 1991, 2000 and 2010



Source: USDA (2016b), National Institute for Food and Agriculture, Salary Analysis of Cooperative Extension Service Positions, US Department of Agriculture, Washington, DC. https://nifa.usda.gov/data.

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Intellectual property rights for biological innovations

Whereas public R&D can justify the cost of research by pointing to society-wide benefits, the costs of private R&D must be outweighed by the benefit to the performing firm alone. Private firms deploy a number of approaches to maintain exclusive control over their discoveries. The menu of options available, especially for plants and animals, has expanded considerably over time, concurrent with the rise in private agricultural R&D as a share of all agricultural R&D (Table 7.3). This section is based on Janis and Kesan (2002); Moschini (2001) and Lemley (2008).

The use of **Trade Secrets** has played an important role in protecting intellectual property in agriculture. So long as firms make a reasonable effort to maintain the secrecy of an economically valuable discovery, the law forbids rivals to discover the product by certain prohibited means (for example, corporate espionage). Notably, independent invention and reverse engineering do not fall under these prohibited means, which has tended to make trade secrets applicable only in some technological domains. In agriculture, hybrid seeds are particularly amenable to trade secrecy protection, because replicating the performance of the seed in future generations is nearly impossible without the parent lines, which are held privately by the firm. However, commercial production of hybrid seed is only viable for a few commodities (maize, sorghum, some vegetable species, and in animal breeding, to poultry and pigs), and private R&D in breeding historically focused on these commodities. Trade secrecy protection is based on state-level, rather than federal legislation. Although 48 states have adopted a version of the Uniform Trade Secrets Act, state-level modifications to the act, as well as state-level differences in interpretation of the act by courts means there is some variation in trade secrecy protection across the country.

Table 7.3. Intellectual Property Rights for agricultural innovations in the United States

Type	Year available	Length of protection	Eligibility criteria	Limitations
Trade Secrecy	Grew out of common law beginning in 1837	Indefinite	- Economically valuable information not generally known - Firms make reasonable efforts to maintain secrecy	- Reverse engineering is not protected - Independent invention is not protected - State-level enabling legislation is not uniform across country
Plant Patents	1930	20 years	- Asexual plants - At least one distinguishing characteristic - Nonobvious - Not sold or released in US more than one year prior to application	- Tubers are not eligible
Plant Variety Certificates	1970 (with 1994 amendments)	25 years for trees and vines 20 years otherwise	- Sexually reproducing plants and tubers - New - Distinct - Uniform - Stable	-Farmers may save seeds that result from growing for reuse (but not resale) - Researchers may use for breeding and other bona-fide research
Utility Patents	1790 (extended to plants and animals in 1980)	20 years	- "Anything made by man under the sun" - Novel - Useful - Nonobvious	- Must disclose invention so that someone skilled in the relevant arts can replicate

Newly discovered asexually reproducing plants (excluding food tuber crops like potatoes) have been eligible for **Plant Patents** since the Plant Patent Act of 1930. To be eligible for a plant patent, a plant must differ from known related plants by at least one distinguishing characteristic, must not have been sold or released in the United States more than one year prior to the date of the application, and must be nonobvious to one skilled in the art at the time of invention. A plant patent gives the assignee the right to exclude others from asexually reproducing, selling, or using the patented plant for a period of 20 years. At that point, the plant becomes part of the public domain.

Protection for newly discovered varieties of sexually reproducing plants, and tubers, was extended by the Plant Variety Protection Act of 1970 and its 1994 amendments, which established a system of **Plant Variety Protection Certificates (PVPC)**. Plants must be new, distinct, uniform, and stable in order to receive a certificate, and must provide seeds to a public seed bank. Upon being granted the certificate, the plant has protection from resale and commercial use for 20 years (25 years for trees and vines). There are a number of exceptions to the protections provided by plant variety certificates though. Most important are the saved seed exemption, which allows farmers to retain and use (but not sell) the seed that results from growing the protected plant, and the research exemption, which allows use of the protected plant for breeding and other bona fide research. These exemptions mean PVPCs provide a more limited form of intellectual property rights than standard utility patents. While PVPC's facilitate wider use of new seeds to stimulate further innovation, patents have generally held higher economic value for innovating firms (Fuglie et al., 2016).[2] The United States is a member of the 1991 UPOV convention, which established harmonised plant breeder rights among members.

Utility patents (hereafter patents) have a much longer heritage, being established in the United States in 1790. Originally, five categories of subject matter were patentable; machines, compositions of matter, articles of manufacture, processes, and improvements in each of the preceding. Discoveries that are novel, non-obvious, and useful are eligible for patent protection which entails a 20 year right to exclude others from commercial exploitation of the innovation. In exchange, the patent holder must disclose the invention, providing enough information for someone skilled in the relevant arts to replicate it.

The understanding of what subject matter is eligible for patent protection has changed over time. Until 1980, plants and animals were viewed as products of nature and therefore *not* eligible for patent protection. Nonetheless, patents remained an important incentive for agricultural innovation in other agricultural input sectors, such as farm machinery. Patent rights were extended to plants via the Supreme Court case Diamond vs. Chakrabarty (1980) which established multicellular living plants and animals are not excluded from patent protection, a decision that was reaffirmed by *ex parte* Hibberd (1985) for plans and ex parte Allen (1987) for animals. Now, the same new crop variety may obtain a Plant Variety Certificate and a utility patent. Plants protected by utility patents do not have saved seed or research exemptions, and so they offer a more stringent form of intellectual property rights. This stimulates private investment in plant breeding, but imposes higher costs for farmers and other researchers. There is widespread use of patents for transgenic crops.

Tax incentives for R&D

Because intellectual property rights are imperfect, private sector R&D may be underprovided, relative to society's best interests. To encourage private firms to engage in R&D, the government offers a number of tax incentives. At the federal level there are three such provisions. These include the deduction from taxable income for research expenses, a tax credit for increasing research activities, and an exemption for donations to charitable agricultural research organisations. As of 2015, each of the incentives is permanent.

The deduction for research expenses allows businesses to elect to deduct from taxable income the entire amount of eligible R&D expenditures in the year in which they were incurred. Without this provision, expenses associated with the development or creation of an asset having a useful life extending beyond the current year must be capitalised and depreciated over its useful life. Eligible R&D costs generally include all costs incurred in the experimental or laboratory sense related to the development or improvement of a product. Examples of qualifying costs include salaries for those engaged in research or experimentation efforts, amounts incurred to operate and maintain research facilities (e.g. utilities, depreciation, rent), and expenditures for materials and supplies used and consumed in the course of research or experimentation.

The federal R&D credit is an incremental credit designed to encourage businesses to increase R&D spending. Under the credit, businesses are allowed to reduce their federal income tax by an amount equal to 20% of their qualified R&D expenditures in excess of a base amount. The base amount is determined by multiplying a fixed-base percentage and the average sales over the preceding four years. For most businesses, the fixed base percentage is the average ratio of R&D expenses to sales over the five-year period 1984-88. A special rule allows new businesses without sales during the period to utilise a specified base percentage of 3% of gross receipts for their first five years.

The base credit is extremely complex and businesses may elect an alternative simplified credit. The simplified credit allows a credit equal to 14% of research expenses in excess of 50% over the average qualified research expenditures for the three prior years.

Qualified research expenses must be experimental, for the purpose of discovering information that is technological in nature and used in the development of a new or improved product, process, formula or invention. Eligible expenditures are limited to direct wage and salary, supplies, costs for equipment and from 65% to 100% of contract research expenses. The credit is not refundable. However, it can be carried forward for 20 years to reduce future tax liability.

A variety of farming and food manufacturing and processing activities are potentially eligible for the credit. Examples include developing new or improved strains of crops or livestock, developing new or improved processes for maintaining food quality and safety, new or improved feeding or breeding techniques for livestock and new or improved production processes for efficiency and waste reduction.

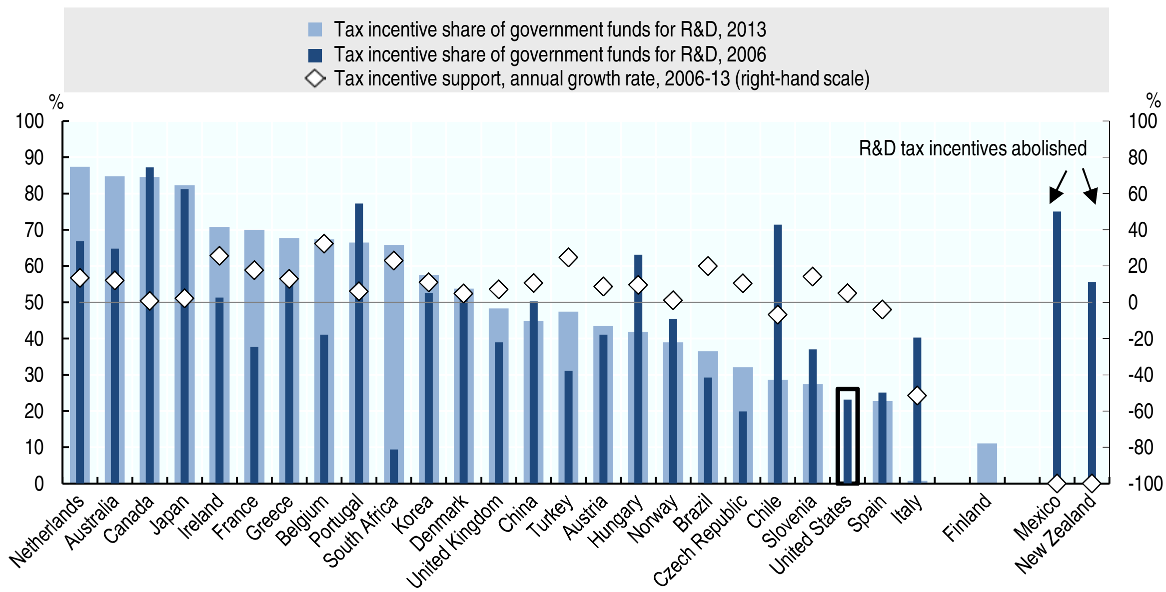
The federal R&D credit primarily benefits manufacturing and professional, scientific and technical service firms with over 75% of the total credit going to such firms in 2008. This would include many firms involved in food processing and suppliers of inputs to agricultural producers. However, only about 0.1% of the credit was received by firms involved in agricultural production. The credit primarily benefits large corporations with about 87% of the credit going to firms with over USD 50 million in assets in 2008.

Since the enactment of the federal credit for R&D expenses in 1981, both the number of states offering such a credit and the level of the credit have increased steadily. Currently, as many as 39 states have adopted a credit for R&D expenses and as of 2005 the average effective rate of the various state level credits had reached 6% of qualified R&D expenditures (Wilson, 2005). In many instances, these credits generally follow the federal guidelines with regard to eligible expenses and the incremental nature of the credit. However, there is some variability in the types of eligible expenditures and the base for determining the incremental expenditures to which the credit rate is applied.

Charitable donations to agricultural research organisations (AROs) are also eligible for exemptions. In 2015, new legislation on the treatment of AROs was passed, modelled on the treatment of medical research organisations. AROs are now considered public charities, regardless of their source of funding and donations are eligible for the higher individual limits, if the organisation commits to use the funds for agricultural research within five years.

Over the period 2006-13, tax incentives as a share of government support for business R&D has increased slightly but remains lower than in most OECD countries (Figure 7.16).

Figure 7.16. Change in government support for business R&D through direct funding and tax incentives, 2006-13



For the United States, 2013 data is replaced by 2012 data.

Source: OECD (2015), OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society. http://dx.doi.org/10.1787/sti_scoreboard-2015-en.

Public-private research collaboration

The growing capability of the private sector in many areas of agricultural research has created new opportunities and challenges in transferring knowledge and technology across sectors. Federal legislation enacted since the 1980s created new mechanisms to encourage public-private collaboration in R&D (Table 7.4). These collaborations can take several different forms (Box 7.3).

Public sector grants to the private sector. In 2014, 30.5% of the Federal Government's R&D spending was conducted by private industry. In the research grant model, the Federal Government funds private in-house research, and has no claims over any patentable discoveries that emerge as a result of research. One example of a private research grant model is the Small Business Innovation Research (SBIR) programme. The **Small Business Innovation Development Act of 1982** requires federal agencies to earmark a portion of their extramural R&D budgets to the funding of research at small businesses, defined as businesses with 500 or fewer employees.

In 2000, the Department of Energy (DOE) and the USDA pooled a portion of their SBIR funds to create the Biofuel Research and Development Initiative (BRDI). Between 2002 and 2006, the agencies contributed about USD 160 million (USD 130 million from the DOE, USD 30 million from the USDA) which was used to fund public and private research for R&D on biofuels, with the majority of funds going to biofuel producers. In general, however, the USDA devotes only a small portion of its R&D funds to research grants to private industry. Total funds allocated to the SBIR programme have grown in real terms, as indicated in Figure 7.18. Nonetheless, in fiscal year (FY) 2011, just USD 18.3 million from a budget of USD 2.6 billion was allocated to industry performers.

Table 7.4. Major US legislation encouraging public-private collaboration in research and technology transfer

Year	Legislation	Action
1980	Stevenson-Wydler Technology Innovation Act	Encouraged government laboratories to increase cooperation with the private sector. Each major government laboratory was directed to create an Office of Research and Technology Applications to facilitate transfer to private companies.
1980	Bayh-Dole Act	Authorised government agencies to grant exclusive licenses to government-owned patents and allowed universities to own patents on research developed with government funds
1981	Economic Recovery Tax Act	Established tax credits for R&D grants to universities for basic research
1982	Small Business Innovation Development Act	Established the SBIR Programme. The programme requires a minimum percentage of each federal agency's extramural R&D budget to be allocated to small businesses.
1986	Federal Technology Transfer Act	Authorised government research laboratories to enter into CRADA with private companies
2014	Agricultural Act of 2014 (Farm Bill)	Established the Foundation for Food and Agricultural Research (FFAR), a non-profit, non-government organisation. FFAR supports joint public-private funding of food and agricultural research
2015	Consolidated Appropriations Act, 2016 (Omnibus Spending Bill for FY16)	Created tax exemptions for charitable agricultural research organisations (ARO). AROs are modelled after medical research organisations established in the 1950s to encourage charitable contributions for medical research.

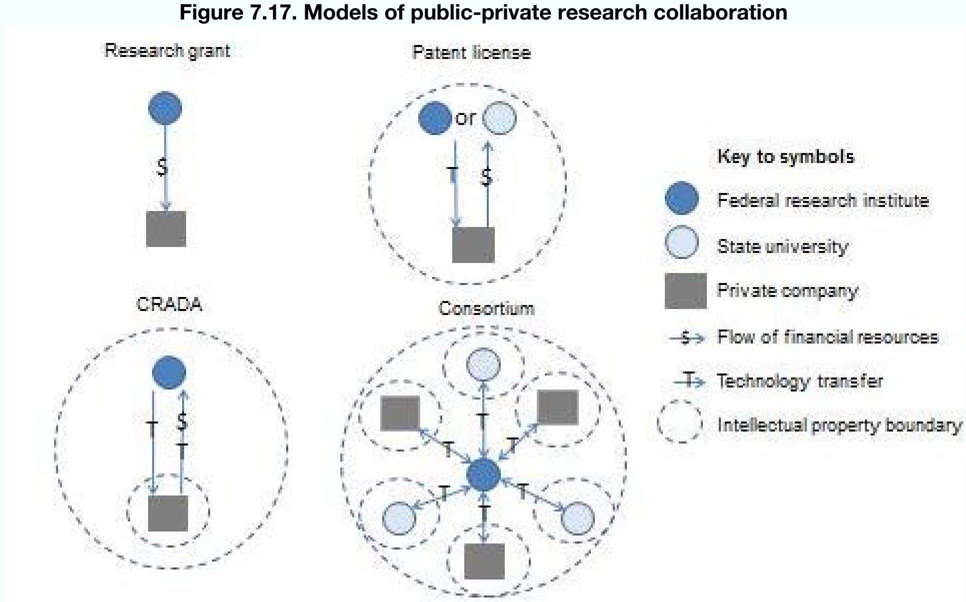
Sources: Schacht (2012), www.nist.gov/mep/data/upload/Industrial_competitiveness_-Technical_advancement.pdf; USDA (2014b), www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=2014/07/0156.xml; and United States Congress (2016) www.congress.gov/bill/114th-congress/house-bill/2029/text.

Box 7.3. Mechanisms for public-private R&D collaboration

US government legislation provides federal science agencies with a number of mechanisms for working with the private sector (Table 7.4). These mechanisms differ in how they finance research and assign rights over intellectual property (Figure 7.17). The appropriate form of collaboration for a specific project depends on several factors, including the characteristics of the research undertaken (e.g. pre-commercial or developmental), the market for the product or service being developed, and the research capabilities of each partner in the collaboration.

The research grant model. The simplest mechanism for collaborative research is for the government to fund private in-house research. In this model there is no formal research collaboration between a government lab and the non-government partner and the grant recipient has sole ownership over any patentable technology. This type of arrangement characterises the SBIR programme and the former Advanced Technology Program. Often, government R&D grants are targeted toward projects of high government priority. In 2000, the USDA and DoE combined a portion of their SBIR resources to form the Biofuel Research and Development Initiative (BRDI). The BRDI provided research grants to companies for biofuel-related "plant science research" and "biorefinery demonstration and deployment" projects, as well as feasibility studies on next generation biofuels (Fuglie et al., 2011).

Figure 7.17. Models of public-private research collaboration



Source: Fuglie and Toole (2014).

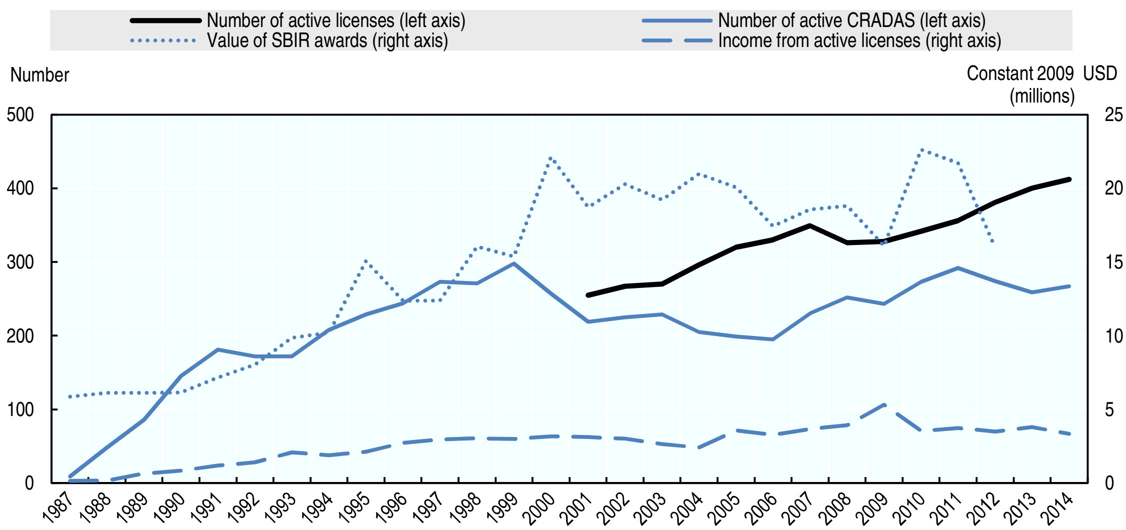
The patent licensing model. Here, a public research institution develops and patents a technology and then assigns the rights to use the patented technology to non-government institutions or private companies. The rights may be exclusive, partially exclusive, or nonexclusive (Heisey et al., 2006). Exclusive patent licenses are awarded when they are deemed necessary to promote private commercialisation — for example, when a company must make significant investments in product and market development, or when substantial commercial risk is involved. Patent licenses usually include a royalty payment that returns either a fixed fee or a percentage of revenues to the public institution that owns the patent.

The joint-venture model: Cooperative Research and Development Agreements (CRADA). A CRADA typically involves a government laboratory collaborating with one company to develop a technology for a specific commercial application. Both parties commit in-house resources to R&D, and the non-government collaborator may provide the government laboratory with some research funds. Government laboratories may provide personnel, equipment, and laboratory privileges, but not financial resources, to a non-government partner. Patents resulting from a CRADA may be jointly owned. The non-government partner has first right to negotiate an exclusive license for those patents resulting from a CRADA that are solely owned by the government. Some data also may not be publicly disclosed for a certain period of time (Day-Rubenstein and Fuglie, 2000). The first CRADA that was established by a federal agency following the passage of the 1986 Technology Transfer Act was between the USDA and Embrex, Inc., which led to the commercialisation of a method for vaccinating poultry against disease before they hatch.

The research consortium. Unlike a CRADA, which involves only one private and one public partner, a consortium brings together several private companies to undertake joint research, with or without a public sector partner. Consortium members contribute resources for the research, which is usually pre-commercial, and have first rights to technologies developed by the consortium. Companies can protect spinoff technologies through trade secrets or new exclusive patents. Research consortia have proven useful for increasing support for research that is considered to be long term and high risk, and for research to develop common standards in an industry. Additional applied and adaptive research is often required, however, to develop and diffuse technology to farmers or other users. Thus, a consortium often relies on the in-house research capacity of its members to develop specific applications from the more generic results of consortium-sponsored research. The Germplasm

Enhancement of Maize (GEM) project is an example of a public-private research consortium in agriculture. GEM was established in 1994 to increase biodiversity in maize cultivars developed by the private sector. GEM's membership includes the USDA, several Land Grant universities, more than 20 seed domestic and international companies, and some foreign public institutions.

Figure 7.18. Public-Private Research Collaboration by the USDA, 1987-2014



Implicit GDP price deflator used to adjust dollar values for inflation (Economic Report of the President, Table B-3).

Sources: CRADA and licensing data from USDA (2014b), Agricultural Research Service Office of Technology Transfer. www.ars.usda.gov/business/Docs.htm?docid=24718; SBIR data from Small Business Innovation Research (SBIR) and Small Technology Transfer Research (STTR) (2014), Small Business Administration. www.sbir.gov/awards/annual-reports.

StatLink http://dx.doi.org/10.1787/888933409044

The 2014 Farm Bill established the Foundation for Food and Agricultural Research, a non-profit corporation that seeks private donations in order to fund agricultural research. The Foundation was initially endowed with USD 200 million from Congress, with the condition that it be matched by non-federal funds. As of 2016, it was operating a Rapid Response Program, designed to rapidly fund research that responds to sudden and unanticipated challenges to the food and agriculture system, and New Innovator programme that sponsored young researchers in food and agriculture sciences.

Patenting and licensing by public institutions to foster private innovation. The cost of public R&D is justified by the benefits to society provided by new discoveries. To benefit from public R&D, discoveries made with federal R&D funds need to be used by society. Traditionally, the fruits of agricultural R&D have been distributed to end consumers via extension services, or more indirectly through academic and government publishing. Patented discoveries made with federal R&D funds were required to issue nonexclusive licenses to help distribute government funded discoveries as widely as possible. Moreover, any revenues associated with patents based on federal R&D were shared with the government, a practice justified by the government's role in funding the R&D.

However, bringing an innovation to market requires a different set of capabilities than those that led to initial discovery (and typically requires additional expense). Because universities and federal agencies usually do not have these capabilities, they often license their innovations to private firms that do. However, if universities must share their license revenue with the government, they may have a reduced incentive to search for these firms. Furthermore, firms make a costly and risky investment by bringing new innovations to market, and a nonexclusive license reduces the profit they can earn. The **Bayh-Dole Act** of 1980 was intended to facilitate the transfer of knowledge between federally funded sources and society by permitting organisations to retain all patent revenues and issue exclusive licenses of patented discoveries made with federal funds. It was complemented by the **Stevenson-Wydler Technology Innovation Act** of 1980, which mandated federal agencies develop specific mechanisms for disseminating government funded innovations. Prior to the passage of the act, technology transfer activities were voluntary.

The USDA has a long history of licensing to the private sector and has made use of the expanded licensing rules that followed the Bayh-Dole Act. The USDA ARS has more than 400 active patent licenses as of 2014, including some exclusive licenses (Figure 7.18). While licensing revenue has been on the rise in real terms, it remains a relatively small as a share of the ARS budget. Through the 2000s, annual licensing revenues were around USD 3 million annually, compared to an annual ARS research budget of USD 1.1 billion. Instead of being used to augment ARS R&D resources, licensing is primarily used as a vehicle for facilitating technology transfer.

Public-Private Cooperative R&D Agreements (CRADAs). As private agricultural R&D rises, so does the research capacity of the private sector. Given the relative specialisations of the public and private sectors, there are new opportunities for direct research collaboration. Collaboration was facilitated by a set of legislation passed in the 1980s and 1990s.

The **1986 Technology Transfer Act** provided conditions under which federal laboratories could work directly with the private sector. Previously, direct collaboration between government researchers and industry was not permitted. Under the rules laid out by the act, public and private research partners could develop a Cooperative Research and Development Agreement (CRADA). A CRADA is a written agreement specifying the resource commitments and responsibilities of each partner. The National Defense Reauthorization Act of 1991 and the National Technology Transfer and Advancement Act of 1995 clarified rules for revenue sharing arrangements in CRADAs.

Typically, a CRADA involves a government laboratory and one company, both of whom contribute in house resources. While the company may contribute in kind resources (e.g. personnel, laboratory space, and research equipment) and financial resources, the government can only contribute in kind resources. Resulting inventions (patents) from the collaboration can be jointly owned. The nongovernment partner has the first right to negotiate an exclusive license for those inventions (patents) made under the CRADA that are solely owned by the government. CRADAs may also specify that some data not be publicly disclosed for a period of time.

Federal agencies enter into approximately 3 000 new CRADAs per year. Figure 7.18 depicts the number of active CRADAs at the USDA's primary in-house research agency, ARS. After rising sharply in the years following the passage of the 1986 Technology Transfer Act, the number of active CRADAs has mostly stayed between 200 and 300 since 1994. As of 2014, ARS had 267 active CRADAs. Day-Rubenstein and Fuglie (2000) found the USDA typically contributed 36% of CRADA resources for the set of CRADAs entered into between 1986 and 1995.

To facilitate the commercialisation of public research, the USDA founded the Agricultural Research Partnerships (ARP) network, a loose coalition of more than 30 groups, ranging from private companies to state-sponsored economic development non-profits. To firms who have acquired ARS research outcomes via CRADAs or patent licenses, the network can provide complementary business development assistance, for example mentoring, identification of funding sources (venture capital and angel investors are part of the network), marketing assessments, and so forth. In many cases, ARS research is commercialised by a start-up, who can then draw on ARP network support to develop necessary commercial capabilities. At the same time, the ARP network also works to connect existing firms with relevant ARS resources (e.g. patents, researchers, facilities, equipment).

R&D outputs and impacts

Trends in agricultural science and technology outputs

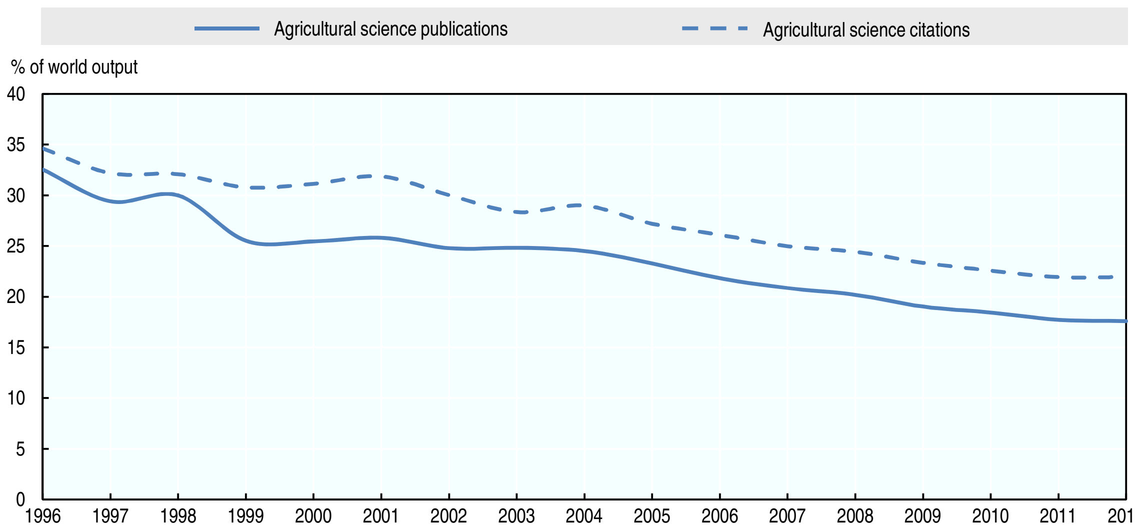
Scientific publications provide one indication of the large role the United States plays in global agricultural science. Like many other countries with substantial scientific research output, agricultural science publications in the United States constitute a relatively small role (less than 6%) of total scientific output. Nonetheless, in 2012 the US share of global agricultural science publications (about 18%) was more than twice as great as that of China, the next highest country. The US share of the world total has declined from nearly a third in 1996, the result of increased agricultural science publication in other countries rather than a decline in US scientific output. Similarly, the United States accounts for over a fifth of all citations to agricultural science publications, the largest share of any country. Again, the US citation share has declined over time for similar reasons to the decline in the publication share. The citation share has been consistently higher than the publication share, suggesting US publications in agricultural science are cited at higher than the average rate (Figure 7.19). Citation analysis has also underlined the importance of public agricultural science for private firms. Private firms' science publications have increasingly cited US public agricultural science publications (Figure 7.20).

Agricultural patents provide another indicator of US agricultural R&D output. Over the period 2006-11, US inventors were granted over 4 500 patents in agricultural science under the Patent Co-operation Treaty (PCT), more than three times the numbers granted to inventors from Germany and Japan, the next largest grantees of agricultural science patents (Figure 7.21). The same pattern holds for general agriculture patents, where the United States total of over 18 000 over 2006-11 was nearly three times the total from Japan, the next highest country (not shown). General agriculture patents may possibly indicate research somewhat downstream from the research reflected in agricultural science patents, just as patents may indicate research somewhat downstream from the research represented by agricultural science publications.

GE crops have been a major emphasis of increased private sector agricultural R&D investment in the United States. Companies wishing to test GE crops in open fields must first obtain approval from the USDA's Animal and Plant Health Inspection Service (APHIS). After collecting the necessary health, safety, and performance data a company must submit a deregulation petition to APHIS before GE crops can be produced and sold commercially. The number of field permit applications and deregulation petitions received by APHIS are often used as measures of R&D activities in agricultural biotechnology (Fernandez-Cornejo et al., 2014). Such approvals rose very rapidly until the early 2000s but have declined since (Figure 7.22). Since real investments in seed and biotechnology research by private companies have continued to rise, the somewhat lower number of field trial approvals may indicate a maturing industry which is now bringing somewhat greater focus to its GE crop research efforts. Over time, companies and other institutions petition USDA for deregulation of a much smaller number of GE crop innovations they wish to market to farmers. Deregulation petitions also show a pattern of a great deal of activity in the late 1990s, followed by a fluctuating and lower level since. Petition approvals naturally lag petition requests (Figure 7.23).

The use of intellectual property protection for new plant technologies and new crop cultivars is sometimes taken as another measure of R&D output in the area of seed and biotechnology. However the use of instruments such as utility patents, PVPCs, and plant patents may also indicate a response to changes in the strength of protection and changes in the scientific environment. There has been a rapid increase in utility patents for both plant cultivars and lines and for general plant modification technologies (including but not restricted to cultivar patents). Although many of these patents have been granted for GE cultivars or technologies, not all of them relate to GE technology. At the same time, the use of PVPCs and plant patents has also increased (Figure 7.24). Companies often apply for both a utility patent *and* a PVPC for the same cultivar, particularly for maize and soybean cultivars, the two most widely patented crops.

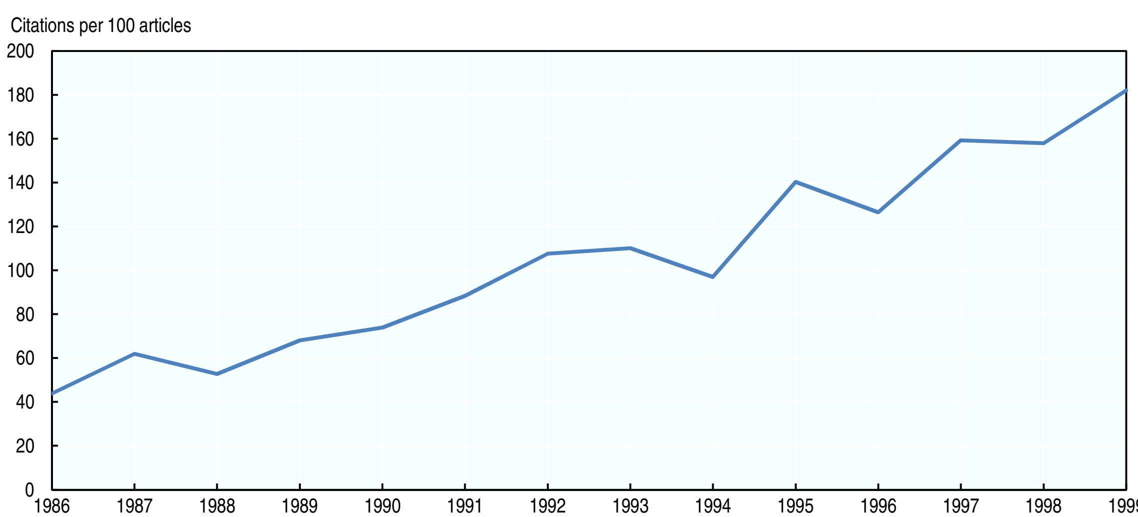
Figure 7.19. US share of global agricultural science publications and citations, 1996-2012



Source: SCImago (2014), *SJR—SCImago Journal & Country Ran*, www.scimagojr.com.

StatLink http://dx.doi.org/10.1787/888933409056

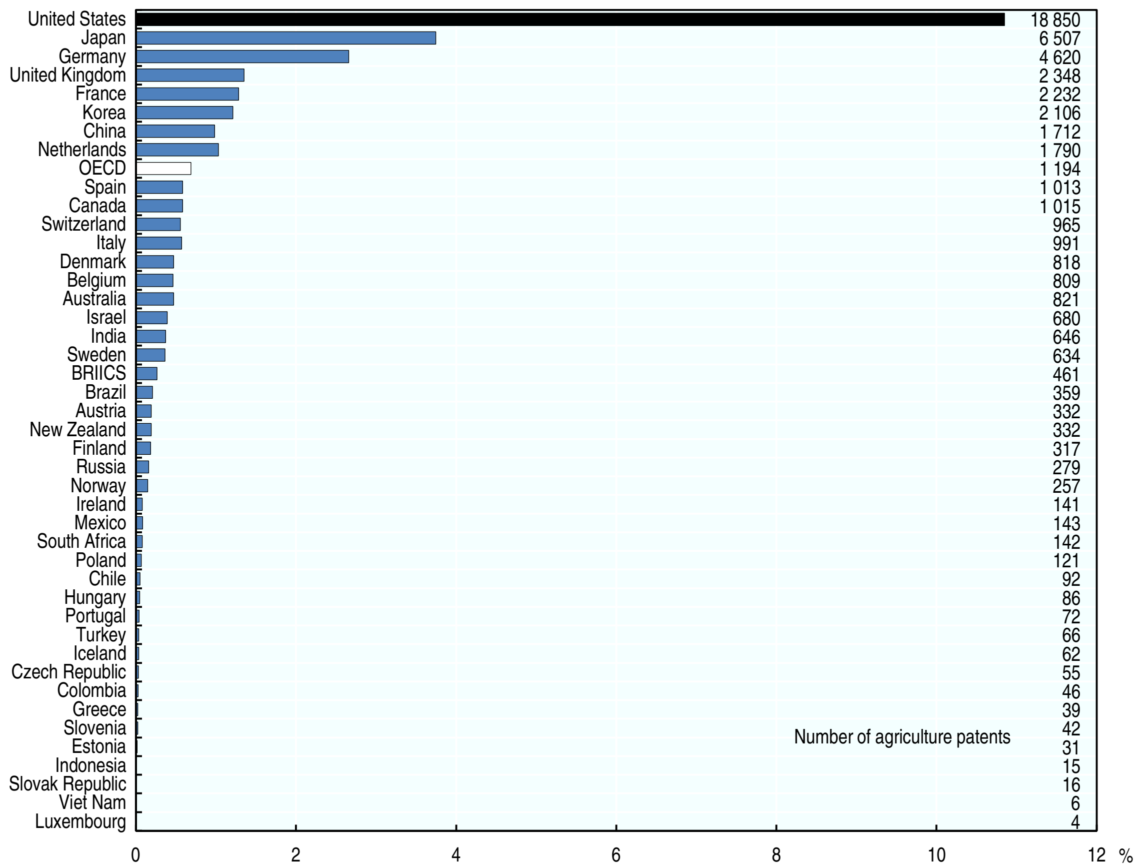
Figure 7.20. Private firms' citation intensity of public agricultural science publications, 1986-99



Source: Toole and King (2011), http://ftp.zew.de/pub/zew-docs/dp/dp11064.pdf.

StatLink http://dx.doi.org/10.1787/888933409060

Figure 7.21. Number of agricultural science patents issued by country, 2006-11



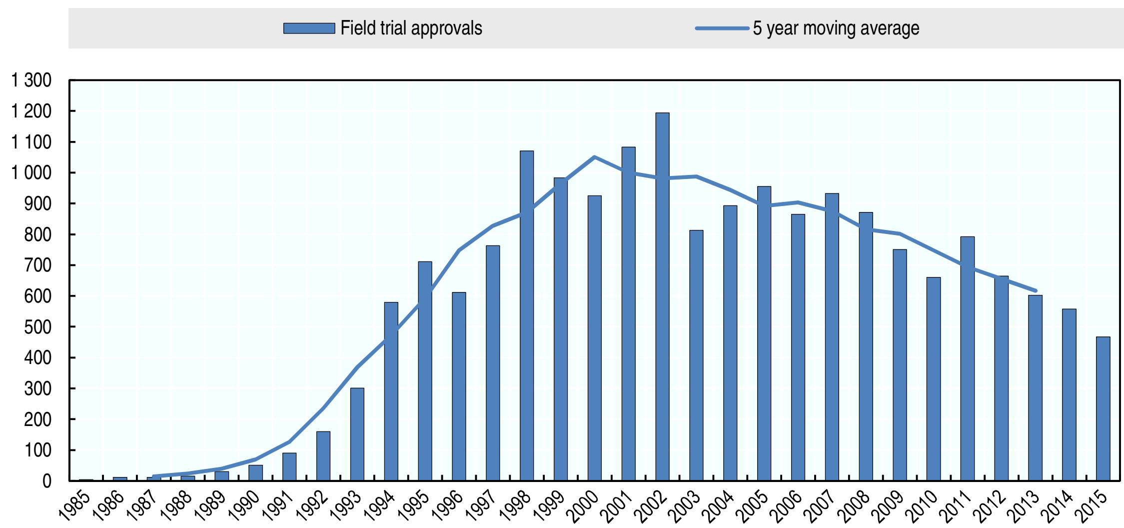
Agriculture includes patents from IPC classes A01, A21, A22, A23, A24, B21H 7/00, B21K 19/00, B62C, B65B 25/02, B66C 23/44, C08b, C11, C12, C13, C09K 101/00, E02B 11/00, E04H 5/08, E04H 7/22, G06Q 50/02.

Patent counts are based on the priority date (first filing of the patent worldwide), the inventors country of residence, using fractional counts.

Source: OECD (2014), Patent Database. www.oecd.org/sti/inno/oecdpatentdatabases.htm.

StatLink http://dx.doi.org/10.1787/888933409075

Figure 7.22. Number of Genetically Engineered (GE) crop variety events approved for field testing by APHIS, 1985-2015[1]

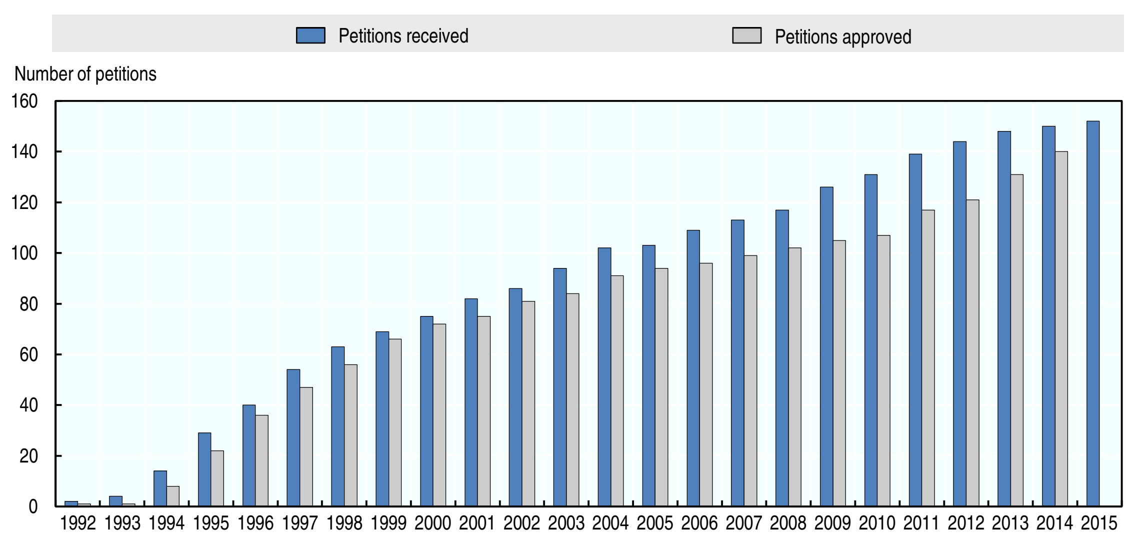


1. Includes permits and notifications.

Source: Information Systems for Biotechnology (2016). www.isb.vt.edu.

StatLink http://dx.doi.org/10.1787/888933409088

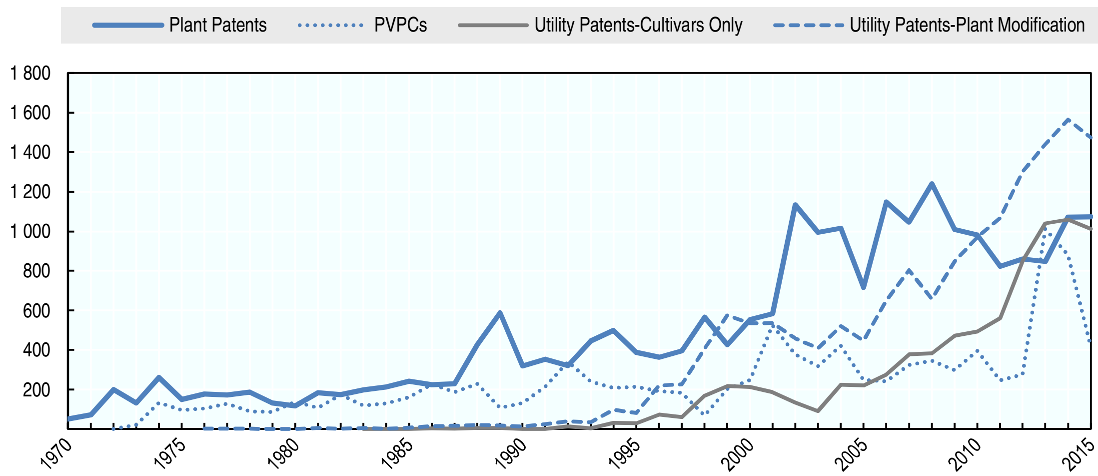
Figure 7.23. Cumulative number of petitions to USDA for deregulation of Genetically Engineered (GE) crops, 1992-2015



Source: Information Systems for Biotechnology (2016), www.isb.vt.edu.

StatLink http://dx.doi.org/10.1787/888933409092

Figure 7.24. Intellectual Property protection for plant varieties and plant modification technology in the United States, 1970-2015



Source: USDA, Economic Research Service, based on US Patent and Trademark Office (USPTO) (2015), US Plant Variety Protection Office (PVPO) databases. www.uspto.gov/patents-getting-started/patent-basics/types-patent-applications/general-information-about-35-usc-161.

StatLink http://dx.doi.org/10.1787/888933409102

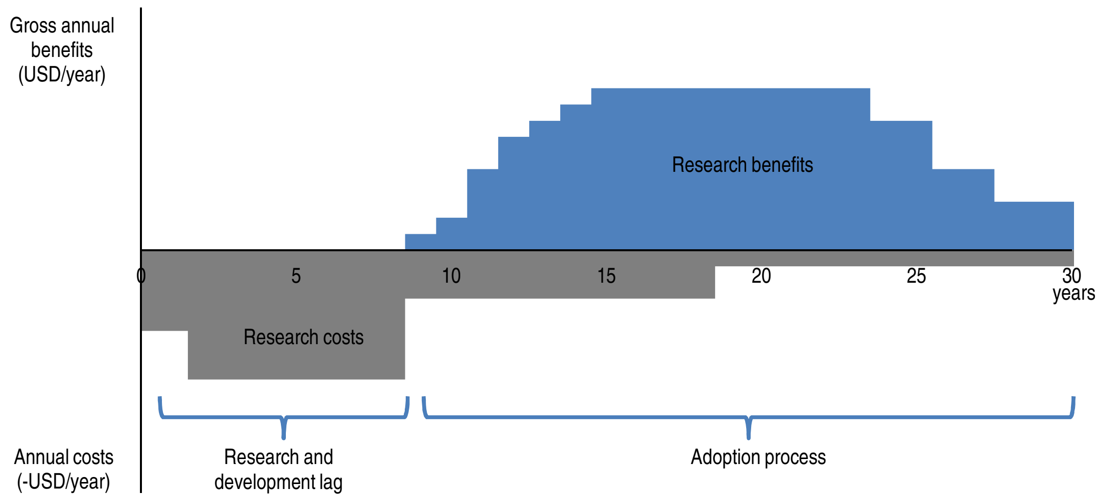
Research impact: Returns to public investment in agricultural R&D

Several studies have evaluated the returns to investment in the US agricultural research system. At the sector level, economic evaluations of agricultural research are typically based on comparisons between 1) public and private investments in agricultural knowledge creation and dissemination, and 2) long-term changes in agricultural productivity. The way this process is conceptualised is:

- Expenditures on agricultural research generate new knowledge that eventually leads to improved technology that is adopted by farmers;
- adoption increases average productivity (the output of crop and livestock commodities per unit of land, labour, capital and intermediate inputs employed in production);
- higher productivity of agricultural resources leads to lower costs, higher production and/or exit of some resources (such as labour) from the agricultural sector;
- given physiological limits to per capita demand for food, higher agricultural production leads to lower commodity prices, passing some of the technology-induced cost reductions on to the food industry and consumers. Thus, benefits of productivity-enhancing agricultural research are shared between the farm and non-farm sectors of the economy.

Figure 7.25 illustrates a typical time pattern of development, adoption and eventual obsolescence of agricultural technology. In the diagramme, a public (or private) institution invests in the development of a new technology (such as a new crop variety with disease resistance) and spends several years working on that effort ("research costs" in the diagramme). In this stylised representation, after about seven years the technology is successfully developed and farmers begin to adopt it. Costs are still incurred in extension efforts, and benefits grow as more farmers adopt the technology and reap higher yield or lower production costs. In the diagram, it takes about eight years (from year 7 until year 15) for the technology to be fully adopted and benefits maximised thereafter. But after some time the technology eventually goes out of use, either because something better replaces it or because it loses its effectiveness (due to build-up of resistance in the pathogen, for example). An economic evaluation of the research endeavour weighs the size of the research and extension costs against the economic benefits from technology adoption, discounting the benefit and cost streams to measure them in terms of their "present value."

Figure 7.25. Flows of research costs and benefits over time



Source: Alston, Norton and Pardey (1995).

There are two main approaches used to estimate economic returns to agricultural research. One approach is the use of ***Statistical analysis*** to relate past expenditures on research to current changes in productivity. These models try to establish a statistical correlation between when, where, and on what research was done and productivity gains in agriculture. It is usually done at a fairly aggregate level and covers a long period of time. These studies also examine effects of other factors that may contribute to productivity growth, like investments in rural education, extension and infrastructure. If regression analysis finds positive and significant correlations between research expenditures (appropriately lagged) and productivity changes, then this is taken as evidence of a causal relationship. An estimate of the rate of return to research is derived from the regression coefficients. A second approach uses ***Project evaluation methods*** to trace the development, dissemination and impact of specific innovations. A good and early example of this approach was a study by Zvi Griliches (Department of Economics, University of Chicago) in the 1950s on the returns to research on hybrid maize. He estimated the benefits of hybrid maize by measuring the economic value of higher maize yield made possible from this innovation. On the cost side, he estimated the cost of research and extension (by both the public and private sectors) beginning with the work of George Schull of the Carnegie Institution and Donald Jones of the Connecticut Agricultural Experiment Station who developed the theory of hybrid vigour and invented the double-cross method of hybrid seed production.

The project evaluation or case study approach provides a clearer cause-and-effect relationship between agricultural research and productivity growth. But the method has largely been limited to analysis of research "success stories". Regression methods, on the other hand, assess the system at a more aggregate level and take into account expenditures on research that may or may not lead to successes, and therefore tend to give a more balanced measure of average returns to a research system. Both approaches involve estimating relationships between the size of investment in research and the economic value of increased productivity, taking into account the appropriate time dimension between when research is done and when economic benefits are realised such as the case depicted in Figure 7.25. Estimates of social returns to research may be overstated if undesirable outputs (e.g. environmental degradation) are not taken into account. Similarly, social returns may be understated if new technology reduces undesirable outputs.

Some of the most challenging aspects of these models are

- ***Lags***: identifying the appropriate lag relationship between when research is done and when productivity growth occurs.
- ***Spillovers***: accounting for knowledge or research "spillovers" across geographic space. "Spillovers" occur when research done in one state, region, or country contributes to new knowledge or technology that is used in another geographic area.
- ***Attribution***: Many elements come together to contribute to the development and application of new technology to agriculture. In addition to publicly-funded agricultural research, there are contributions made by basic sciences, innovations from the private sector, farmer education, the training role of extension services, improvements to rural infrastructure, and so on. These institutional sources often act in complementary ways and failure to account for the contribution of one source may over-attribute observed gains in productivity to another source. Including all these sources in a model may give an indication of the relative importance of each source (and the relative rate of return to each). Some studies for the United States go even further to try to distinguish returns to agricultural research done by federal or state institutions, or even by different federal funding instruments (e.g. formula versus competitive grants). But putting finer and finer distinctions among sources of innovation and types of research expenditure places a very heavy burden on the data.

Table 7.5 summarises findings from 22 studies, which evaluated the impact of public agricultural research on the productivity of the entire farm sector using the methods described above. Estimates vary due to the methodology employed and time period covered, but all show significant and high returns to research, and the median estimate from these studies is 40%. This means that USD 1 of initial spending on agricultural research generated a stream of economic benefits averaging USD 0.4 per year, with these benefits lasting for several decades. Adding up these benefits and casting them in present values is consistent with a benefit-cost ratio of at least 20:1 (Alston et al., 2011). These studies also found benefits of public agricultural research were widely shared, not only among farmers but also with consumers in the form of more abundant and lower cost food.

Table 7.5. Estimates of the internal rate of return to public investments in agricultural research

Study	Authors	Pub. year	Publication	Period of study	Rate of return to research
1	Jin and Huffman	2016	Agricultural Economics	1970-2004	67
2	Andersen and Song	2013	Agricultural Economics	1949-2002	21
3	Wang, Ball, Fulginiti and Plastina	2012	CABI volume chapter	1980-2004	45
4	Plastina and Fulginiti	2012	Journal of Productivity Analysis	1949-1991	29
5	Alston, Andersen, James and Pardey	2011	American Journal of Agricultural Economics (Ag Econ)	1949-2002	23
6	Huffman and Evenson	2006b	American Journal of Ag Econ	1970-1999	56
7	Gopinath and Roe	2000	Econ, Innov. and New Technology	1960-1991	37
8	Makki, Thraen and Tweeten	1999	Journal of Policy Modeling	1930-1990	27
9	White	1995	Journal of Ag and Applied Econ	1950-1991	40
10	Chavas and Cox	1992	American Journal of Ag Econ	1950-1982	28
11	Norton and Ortiz	1992	Journal of Production Agric.	1987	58
12	Yee	1992	Journal of Ag Econ Research	1931-1985	54
13	Braha and Tweeten	1986	Tech. Bull., Oklahoma State U	1959-1982	47

Table 7.5. Estimates of the internal rate of return to public investments in agricultural research (*cont.*)

Study	Authors	Pub. year	Publication	Period of study	Rate of return to research
14	Lyu, White, Liu	1984	Southern Journal of Ag Econ	1949-1981	66
15	White and Havlicek	1982	American Journal of Ag Econ	1943-1977	22
16	Davis	1979	PhD thesis, U Minnesota	1949-1974	60
17	Knutson and Tweeten	1979	American Journal of Ag Econ	1949-1972	38
18	Lu, Cline and Quance	1979	Ag Econ Report, USDA	1939-1972	27
19	Bredahl and Peterson	1976	American Journal of Ag Econ	1937-1972	48
20	Cline	1975	Oklahoma State U, PhD thesis	1939-1948	46
21	Evenson	1968	U Chicago, PhD thesis	1949-1959	47
22	Griliches	1964	American Economic Review	1949-1959	33
	Median estimate				40
	Low - to - high estimate				21 - 67

Source: See references.

Adoption of innovations

Agricultural innovations occur when farms adopt new technologies and farm practices, develop new enterprises, or achieve economies of scale. The aggregate changes in agricultural productivity described in previous chapters are the cumulative effect of the adoption of such innovations. Adoption is largely driven by the desire of producers to increase the profitability of their farm operations. Market forces and price signals serve as powerful instruments to spur rapid adoption of productivity-enhancing technologies and practices. Extension and education activities, provision of financial and risk management services, and access to commodity and input markets improve the flow of information and uptake of innovations by farmers. But in cases where externalities are present (i.e. when what one farmer does affects other people), market incentives alone may be insufficient to incentivise adoption. Achieving effective control of plant and animal pests and diseases, mitigating environmental impacts of agricultural production practices, and assuring the quality and safety of food products, are cases where technological and informational externalities may require collective or government action to achieve widespread adoption. This section illustrates these dimensions of the innovation process by drawing on examples from US agriculture.

Technological change in maize production

Maize, the single most import crop in US agriculture, provides a good illustration of the cumulative and multifaceted nature of technical change in agriculture. Over the past century, land and labour productivity in maize production have risen dramatically. Between 1900 and 1974, the hours of labour required to produce 100 bushels of maize fell from 179 to 4 (Sundquist et al., 1982). Average maize yield, which remained static at around 1.6 metric tonnes (MT) per hectare (ha) (26 bushels per acre) between 1866 and 1940, rose to 10.7 MT per ha (170 bushels per acre) in 2014. Since the 1930s, maize production rose from 50 million MT of grain to an annual average of more than 350 million MT (in 2013-15). At the same time, the total area harvested for grain remained constant at about 34 million ha. Yield of maize silage (grown on an additional 2.5 million ha) also increased, from about 2.4 MT per ha in the 1930s to over 7 MT per ha today.

One of the first major technological changes to affect US maize production was the conversion from animal and human power to mechanised power for farm operations. By the 1960s, tractors, combines and trucks had largely replaced draft animals in field cultivation, harvesting and farm transport.

Not only did mechanisation reduce labour requirements, it freed up large amounts of cropland that had previously been used to produce forage and feed grain for draft animals. Farms could now devote more land to commercial crop and livestock production. Olmstead and Rhode (2001) estimate that roughly 22% of the output all cropland harvested over the 1880 to 1920 period was consumed by farm draft animals. By 1960, when the replacement of draft animals by tractors and other farm machines was largely complete, this land had been converted to other uses, including commercial crop production and cropland retirement for environmental and recreational purposes.

Breaking the link between crop production and feed requirements for draft animals facilitated the regional specialisation of commodity production. Regions where maize could not be grown efficiently could now convert that land to other uses; and regions where maize was best suited could now grow maize on lands previously needed for pasture and forage crops. Beddow and Pardey (2015) estimate that regional specialisation in maize production accounted for as much as 21% of the increase in average national maize yield between 1909 and 2007. The regional specialisation in maize production closely mirrored where pigs were raised, since farmers historically have converted their surplus maize production into pigmeat as a means of adding value to farm production.

After 1940, there was a revolution in maize yield. The intensification of maize production can be attributed to the development and adoption of a series of innovations involving varietal improvement, fertilisation, pest and disease management, advancement of irrigation, and changes in soil tillage practices (Figure 7.26). Between the 1930s and the 1950s, hybrid seed varieties gradually replaced open-pollinated varieties in all major maize-growing states. One characteristic of improved maize hybrids is that their erect structure has allowed farmers to steadily increase planting density. Between 1930 and 2000, seeding rates rose from about 30 000 to over 80 000 plants per ha (Duvick, 2005).

Another major innovation in seed technology began in the 1990s, when the first GE crop varieties became available. GE crops have had genes inserted into them that provide specific traits. The principal traits introduced to-date are insect resistance and herbicide tolerance. The most recent GE hybrids have "stacked" traits involving multiple inserted genes. Additional GE traits in the development "pipeline" include drought tolerance, improved nitrogen utilisation, and enhanced quality characteristics for animal feed (Parisi et al., 2016). The first commercial GE maize variety was adopted in the United States in 1996. By 2013 GE maize varieties had spread to 90% of total maize acreage in the country (Fernandez-Cornego et al., 2014).

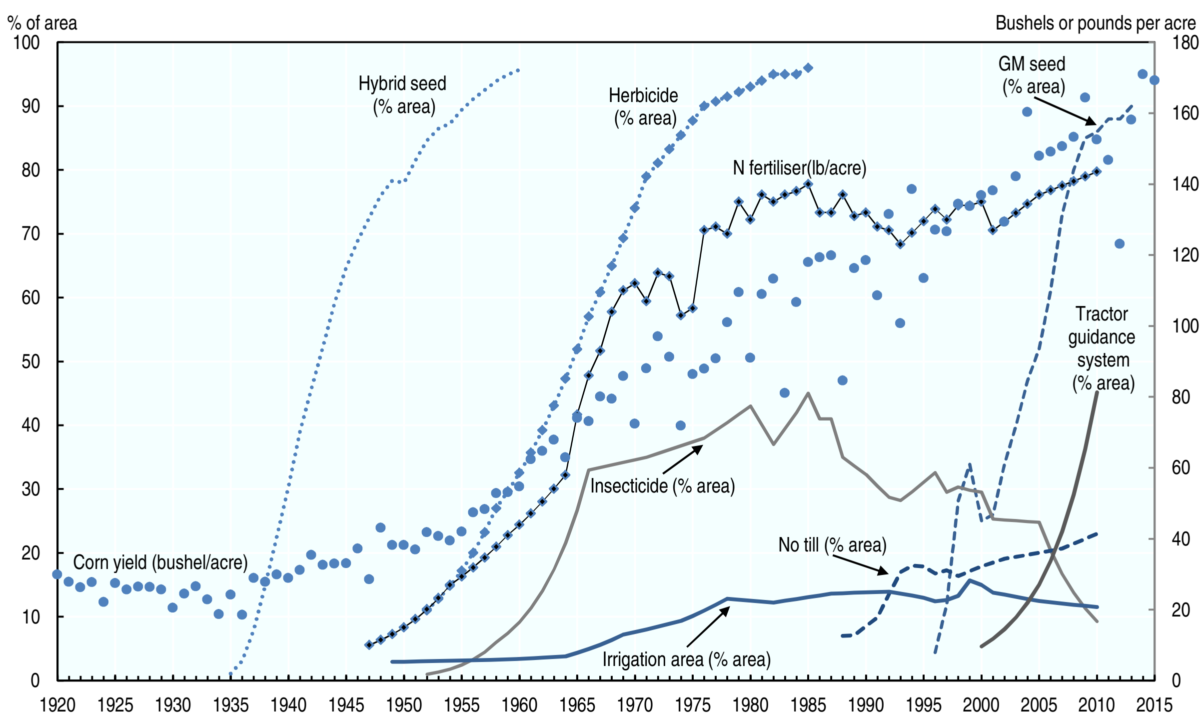
In addition to new varieties, several other technologies and cropping practices have been adopted by maize growers to raise productivity. After WW II, farm applications of inorganic fertilisers and chemical pesticides rose significantly. The increase in fertiliser and pesticides was necessary to realise the higher yield potential in the new hybrid varieties that were adopted during this period. Nitrogen fertiliser use rose very rapidly from under 22 kg per ha (20 pound per acre) in 1950 to nearly 157 kg per ha (140 pounds per acre) by the mid-1980s. Between 1960 and 1982, the share of maize acreage treated by herbicides rose from less than 10% to more than 95%, and has remained at about that level since. Insecticide use never reached more than 45% of maize area, and subsequently fell to only about 25% of acreage in the mid-2000s. The advent of GE maize varieties resistant to major maize pests reduced the need for insecticides (however, seeds are commonly coated with insecticides and fungicides to improve their viability, but at much lower rates than field spraying).

Two important cropping practices that affecting maize productivity are the use of irrigation and no-till cultivation. The share of maize under irrigation expanded slowly since the 1950s to reach 12-15% of total acreage by the 1990s, and has remained at about that level since. No-till maize took off rapidly in the early 1990s and reached 23% of total area by 2010 (Wade et al., 2015). Adoption of these new technologies and cropping practices are often complementary: no-till maize is often used together with herbicide-tolerant GE varieties and herbicides, with the seed-chemical combination acting as a substitute for the use of mechanical tillage for weed control. Some important advantages of no-till include significantly reduced soil erosion and lower machinery, fuel and labour costs, which have to be compared with the impact of higher herbicide application.

Recently, new information technologies have been developed and applied in maize production under the general heading of precision agriculture. Precision agriculture encompasses an evolving suite of practices that include the use of yield monitors; variable rate applicators for fertilisers, chemicals and irrigation water; autosteer tractor guidance systems: and sensors to detect emerging biotic and abiotic yield stresses during the growing season. The use of autosteer tractor guidance systems has expanded rapidly in maize production, rising from less than 5% of planted acres in 2000 to 45% by 2010 (the last year for which comprehensive statistics are available). By enabling more precise and less demanding field operations (such as planting), autosteer tractor guidance systems have saved labour, fuel, seed, and extended the work-day during the critical planting season. This has enabled farmers to maintain sown area even in years where untimely rainfall or late winter thaw shorten the period available for planting.

The sets of new technologies described above served to increase maize productivity by saving resources, namely the amount of land, labour, chemicals, energy and machinery, needed to produce a given quantity of output. Saving these resources reduced the unit cost (cost per bushel) of producing maize. These costs savings increased the profitability of farming and made US maize producers more competitive in international markets. Some of the gains from productivity were also passed on to the food industry and consumers in the form of lower prices for commodities, which results from the increased supply of maize to markets.

Figure 7.26. Crop yield and technological change in maize production, 1920-2015



Some series are only available periodically. For these series, adoption rates for intervening years have been interpolated.

Sources: Maize yield and hybrid seed area are from the USDA (2015f), *Agricultural Statistics*. Maize irrigated area is from USDA (2015g), *Census of Agriculture*. Adoption rates for herbicides, insecticides, no till, tractor guidance systems, and N application rates for fertiliser are from the USDA (2015h), Economic Research Service. GM seed adoption rates are from Fernandez-Cornejo et al. (2014).

StatLink http://dx.doi.org/10.1787/888933409118

Innovation and structural change in the pig industry

The US pig industry provides a striking example of how innovation and structural change combine to produce productivity growth (McBride and Key, 2013). In 1992, about 190 000 farms had swine onsite. Most were "farrow-to-finish" farms that combined all life stages of pig production, along with the production of crops for feed. Pigs were sold through cash markets to local packers.

All that changed rapidly in the next few years. Production shifted to fewer but larger farms. By 2012, the number of farms with swine had fallen by two-thirds to 63 000 farms, even as total production increased. The new system featured farms that specialised in single stages of pig production, such as farrow-to-wean, wean-to-feeder, or feeder-to-finish, and which were linked together through production contracts (Table 7.6). Most still produced crops, using pig manure as an input, but feed was purchased and some farms specialised only in pigs.

Under production contracts, firms called integrators provide contract growers with feeder pigs, age-specific feeds, veterinary services, and technical advice. Contract growers are paid fees per animal or per pig space, which may also be tied to target values for feed conversion and mortality. Integrators that are also processors manage placements of pigs on farms, and flows to packing plants to meet demand and minimise processing costs. Integrators that are not processors typically sell market pigs to processors under marketing contracts specifying weekly and daily flows of animals to plants, and that tie pig prices to pig attributes.

The new system facilitated a set of interrelated innovations. Genetic adjustments could be introduced rapidly, on a large scale. On-farm technologies — such as all-in/all-out production (where, to control the spread of diseases only pigs of similar age are housed together and facilities are cleaned and disinfected between generations), feed formulations tied to the phase of production, artificial insemination, and improved ventilation and sanitation in houses — were widely adopted and allowed integrators to provide uniform animals to processors at lower costs while also maintaining or improving animal health. With integrators and processors assuming price risks and marketing functions, farmers could be induced to invest in larger facilities to realise scale economies. With steady supplies of pigs, processors also invested in larger production facilities to realise scale economies.

Structural change was associated with striking changes in productivity. Feeder-to-finish farms showed large improvements in feed conversion and labour productivity between 1992 and 2004, and real average production costs fell by over 40% (Table 7.6). Those measures also improved among farms in the traditional farrow-to-finish system, because only the most productive and adaptable of those farms survived.

The gains came through three channels: improvements available to and used by all farms; efficiencies introduced by integrators via the contract system: and new scale economies captured by expanding operations. Scale is an important part of the story, and the impacts are summarised for feeder-to-finish farms in Table 7.7. Farms are sorted into five size classes, and an estimated scale elasticity is reported for each class. The estimate — the percentage change in output attendant upon a 1% increase in all inputs — is based on production functions reported in McBride and Key (2013) and other sources cited therein. In 1998, the estimates exceeded one for each of the four smaller size classes, indicating that farms in those classes could reduce unit costs by expanding output.[3]

Farms responded rapidly to available scale economies. In 1992, only 9.3% of pigmeat output was in the two largest classes, close to constant returns. But by 1998, 65% of production was in the largest two classes, and by 2009, 91% was. That adjustment was an important driver of improved productivity and reduced real production costs during 1992-2009. In turn, those developments limited increases in retail pigmeat prices in the face of sharp increases in feed costs, and led to improved international competitiveness. Annual pork exports increased from 0.5 billion pounds in 1992-94 to 4.0 billion pounds in 2007-09 as the United States became a net exporter.

Table 7.6. Structural change and efficiency in pig production, 1992-2009

Item	1992	1998	2004	2009
Share (%) of all pigmeat production:				
Under contract	5	40	67	71
On farrow-to-finish farms	65	38	18	20
Feeder-to-finish farms				
Average size (head sold per farm)	804	2 756	4 730	7 222
Feed conversion (pounds per cwt gain)	383	282	214	207
Labour rate (hours per cwt gain)	0.89	0.24	0.15	0.12
Production costs (per cwt, 2009 USD)	69.22	51.35	39.69	37.62
Farrow-to-finish farms				
Average size (head sold per farm)	886	1 239	1 472	3 980
Feed conversion (pounds per cwt gain)	416	374	354	300
Labour rate (hours per cwt gain)	1.13	0.72	0.54	0.48
Production costs (per cwt, 2009 USD)	85.89	71.59	62.36	43.86

cwt is hundredweight equivalent to around 45 kg. The production cost estimates are adjusted to 2009 dollars using an input price index derived from a USDA/NASS national feed price index and a USDA/NASS national agricultural production items index, with expenditure weights for each derived from a national survey.

Source: McBride and Key (2013), www.ers.usda.gov/publications/err-economic-research-report/err158.aspx.

Table 7.7. Scale economies and adjustment in feeder to finish operations, 1992-2009

Size class (cwt gain)	1998 scale elasticity	1992	1998	2004	2009
		Share of total output (%)			
<1 000	1.23	14.7	1.9	0.5	0.1
1 000-2 499	1.14	35.0	6.7	3.0	1.0
2 500-9 999	1.08	41.0	26.5	16.7	8.0
10 000-24 999	1.04	9.3	29.2	36.3	46.1
>24 999	0.97		35.7	43.4	44.8

Source: McBride and Key (2013), www.ers.usda.gov/publications/err-economic-research-report/err158.aspx.

Improved feed conversion reduced the environmental risks associated with feed production and manure generation. However, structural change that consolidates pigs on much larger operations also consolidates manure, raising the risks associated with manure storage failures and with excess nutrient applications. US regulatory policy aims to control those risks associated with large operations, while conservation programmes aim to provide incentives to adopt improved control structure and technologies.

Adoption of innovations when externalities are present

There is a class of worthwhile agricultural technologies for which market mechanisms may be insufficient to ensure widespread adoption. Many technologies involving pest and disease control in crops and livestock, for example, may not work effectively at the individual farm-level due to the mobility of these pests. This is a case where technology involves a significant externality, i.e. where the private and the social costs and benefits of technology adoption sharply diverge. US agricultural policy has devised special institutions and policies to incentivise adoption in these cases.

Externalities are often present in pest and disease control. Since pests and diseases can be highly mobile, actions taken (or not taken) on one farm or field may impact neighbouring farms. In some cases it may be possible to completely eradicate an agricultural pest or disease, but only if carried out on a large scale with all affected areas participating. Often, pest control and eradication programmes may be ineffective if confined to a community or state, and need to be coordinated at the federal or even international level.

Animal disease control. US legislation dating back to the late 19th century established the means by which the USDA and other federal government agencies could undertake and require collective action to protect agriculture from major biological threats. In 1884, Congress created the Bureau of Animal Industry (BAI) and authorised it to carry out the necessary scientific research and regulatory controls to address major livestock pest and disease problems. The BAI was able to eradicate a number of highly contagious pests and diseases from the United States, include bovine pleuropneumonia, tick-born Texas fever, Foot and Mouth Disease (FMD), bovine tuberculosis and pig cholera, many of which also infected humans (Olmstead and Rhode, 2015). Achieving these outcomes required scientific advances to understand the nature of the disease, its means of transmission, and to determine options for control. In addition, institutional innovations were necessary to coordinate an inter-state campaign to monitor for disease outbreaks, quarantine affected areas, and treat or destroy affected livestock. One innovation was developing an effective indemnification policy. As farmer cooperation in these efforts was essential, the BAI was authorised to indemnify (compensate) farmers for their losses. But to avoid moral hazard (where the promise of indemnification may discourage farmers to take proper precautions in protecting their livestock) compensation was calibrated according to the severity and ease of transmission of the disease. Full compensation was limited to highly infectious diseases like FMD. In other cases, farmers were offered only partial indemnification for losses. Olmstead and Rhode (2015) document that the economic benefits of these efforts far outweighed their costs.

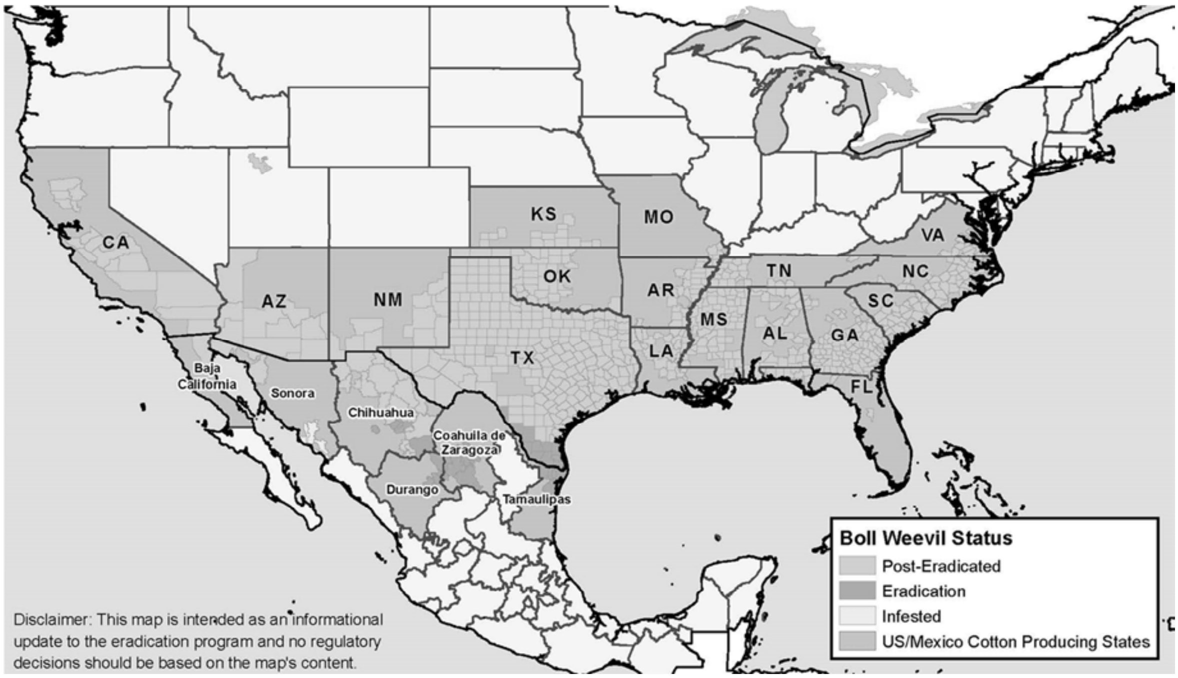
Boll weevil eradication. One of the most devastating pests affecting US crops has been the cotton boll weevil (*Anthonomus grandis*). The boll weevil crossed the border between Mexico and Texas 1892 and by 1924 had spread to all cotton-growing states in the country. Farmers adopted a number of practices to limit damage, such as adoption of early-maturing varieties, destruction of crop residues that might provide over-wintering insect refuges, and, especially after WWII, chemical pesticides. While farmers were eventually able to limit yield losses from the boll weevil, these control practices added considerably to the cost of production. By the 1960s, more than half of all insecticides used in US agriculture were applied to cotton (Ridgway et al., 1978). The widespread use of chemical pesticides also created environmental and health hazards. During the 1960s, scientific advances — especially the discovery of the diapause behaviour of weevil and the synthesis and use of pheromones to trap and monitor insect populations — suggested that it might be possible to eradicate the boll weevil from the United States. However, eradication could only be effective if carried out collectively, as weevils from one untreated field could rapidly re-infect surrounding areas. The 1973 Agricultural Act authorised the USDA to carry out a boll weevil eradication programme if it was considered feasible to do so. In 1978, large-scale field trials demonstrated the efficacy of eradication, and the USDA embarked upon a nation-wide programme. Under the terms of the programme, and to ensure farmer support, the programme was initiated in states where at least 70% of cotton farmers in a state voted in favour of the programme. Participation by all farmers then became mandatory, with about 30% of the costs borne by producers and 70% by the government

(Haney et al., 2009). Eventually farmers in all cotton-produced states voted to participate. International cooperation in boll weevil eradication was also extended to cotton-producing states in northern Mexico. By 2014, the boll weevil had been eradicated from all cotton-growing areas of the United States except for southern Texas, as well as many parts of Mexico (Figure 7.27). Boll weevil eradication led to a significant reduction in pesticide use on cotton fields and greatly improved the profitability of cotton growing. Some states, like Georgia, saw a resurgence of their cotton industry following eradication (Figure 7.28), subsequent to the long period of decline following the first appearance of the pest (Haney et al., 2009).

Screwworm eradication. In some cases, new technologies to control agricultural pests and diseases can be carried out by government authorities without direct participation or actions by farmers. For crops not native to the United States, classic biological control, in which exotic predators of insect pests are identified, multiplied and released, has often been an effective strategy. An example of where scientific advances led to new opportunities for government-led pest control is the case of the New World Screwworm (*Cochliomyia hominivorax*). The screwworm is a maggot that feeds off living flesh, and for decades the screwworm was the cause of suffering, death and expensive treatment measures for livestock. In the 1950s, researchers from the USDA and Texas A&M State University discovered it might be possible to eradicate the screwworm using the Sterile Insect Technique (SIT), in which mass numbers of sterile males would be bred and released to interfere with insect reproduction. After successful local trials the programme was carried out nationwide, and by 1966, one of the greatest scourges of vertebrate animals had been eradicated from the United States (Wyss, 2000). Through a cooperative international effort, screwworm eradication was extended to Central America, and by 2006 the screwworm had been eliminated as far south as the Darien Gap on the Isthmus of Panama. The biological control of screwworm represents a case where government agencies led the application of the technology; farmers were largely passive observers to the dissemination process.

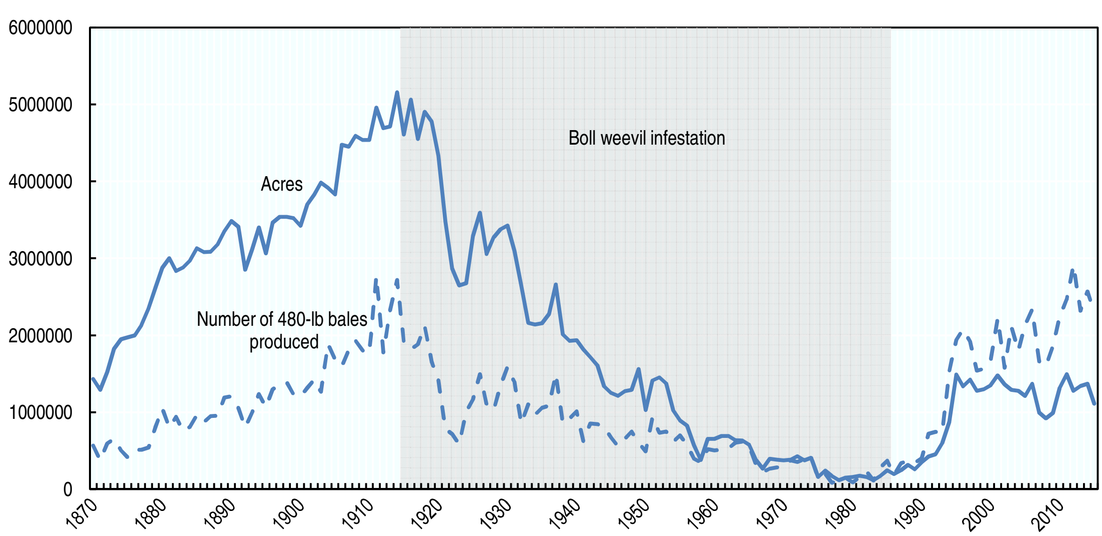
New pests and evolving diseases remain a constant threat to agriculture, whether they have been introduced from external sources, or have evolved to overcoming existing control measures. Recent examples of new threats to US agriculture include HLB disease (citrus greening) first detected in Florida orange groves in 2005, the Porcine Epidemic Diarrhea Virus (PEDv) detected in swine herds in 2013, and the emergence of a new highly infectious strain of avian influence in US poultry flocks in 2015. Each of these diseases has resulted in millions of dollars in economic losses to farm producers and consumers, and effective measures of control are still under development.

Figure 7.27. Cotton boll weevil eradication in North America



Source: USDA (2015i), Animal and Plant Health Inspection Service (APHIS). www.aphis.usda.gov/plant_health/plant_pest_info/cotton_pests/downloads/bwe-map.pdf.

Figure 7.28. The boll weevil and cotton production in Georgia



Source: Cotton statistics from USDA. See Haney et al. (2009) for a detailed assessment of the boll weevil's impact on the Georgia cotton industry. http://extension.uga.edu/publications/files/pdf/RB%20428_2.PDF.

StatLink http://dx.doi.org/10.1787/888933409120

International cooperation

The benefits of international cooperation for national innovation systems stem from the specialisation it allows and from international spillovers of agricultural science and technology. International cooperation in agricultural R&D is particularly important where global challenges (as in the case of responding to climate change) or trans-boundary issues (related to water use or pest and disease control) are confronted, and when initial R&D investments needed to address a common problem are exceptionally high.

With growing capacities in agricultural science and technology elsewhere in the world, US public research institutions have placed greater emphasis on international collaboration to address shared challenges. In addition, the United States continues to give priority to investing in agricultural innovation systems to promote food security in low income countries. Moreover, US agricultural universities attract significant numbers of foreign students, and US foreign agricultural assistance programmes emphasise building national capacities in agricultural sciences in developing countries. This section describes US government engagement in international agricultural R&D cooperation and technical assistance.

International cooperation in agricultural research

The USDA's ARS engages in international collaboration through multilateral and bilateral partnerships. Multilateral partnerships have been particularly effective for controlling agricultural pests and diseases that threaten whole regions of the world. ARS currently participates in the STAR-IDAZ Global Network for Animal Disease Research (which includes specific groups of collaborators working on Foot and Mouth Disease in cattle, African Swine Fever, and avian influenza) and the Borlaug Global Rust Initiative (to combat wheat rust, a fungal disease of global importance). Global and regional partnerships have also been established to address specific resource challenges, such as the Global Research Alliance on Agricultural Greenhouse Gases, the Global Genetic Resources Information Network, and the Middle East Water and Livelihood Initiative.

ARS has formal agreements with nearly 60 countries for research collaboration, and maintains long-term bilateral research agreements with key research partners, including China, Brazil, Israel and Korea. ARS maintains overseas laboratories in France, Australia, and China to study the biological control of exotic pests in order to protect US agriculture against potential invasive species. A major component of ARS international research engagement is direct scientist-to-scientist collaborations, which includes informal scientific and information exchange, hosting visiting scientists, or co-authoring publications.

Measure of R&D collaboration

About 14% of US agriculture patents have a foreign co-inventor, which is more than the OECD average but less than in many countries (Table 7.8). However, the United States is by far the first producer of agriculture-related patents with foreign co-inventor in the world, contributing to more than 10% of the world's total, well above the second largest contributors which are Germany, France and the United Kingdom (Figure 7.29). This can be explained by the large size of the US agricultural research system the importance of research activities by US agri-food enterprises, including plant breeding multinational companies.

The share of publications with foreign co-authors in US agriculture-related publications is lower than the OECD and EU15 averages, but also lower than in Australia and Canada (Table 7.8). Again, reflecting the large size of research activity on food and agriculture within the United States, US publications with foreign co-authors make the largest contribution to all publications on agricultural and food sciences, followed by the United Kingdom, Germany and France (Figure 7.30).

Table 7.8. Agri-food R&D co-operation, 2006-11

Agri-food outputs with co-authors as a share of total agri-food outputs (%)

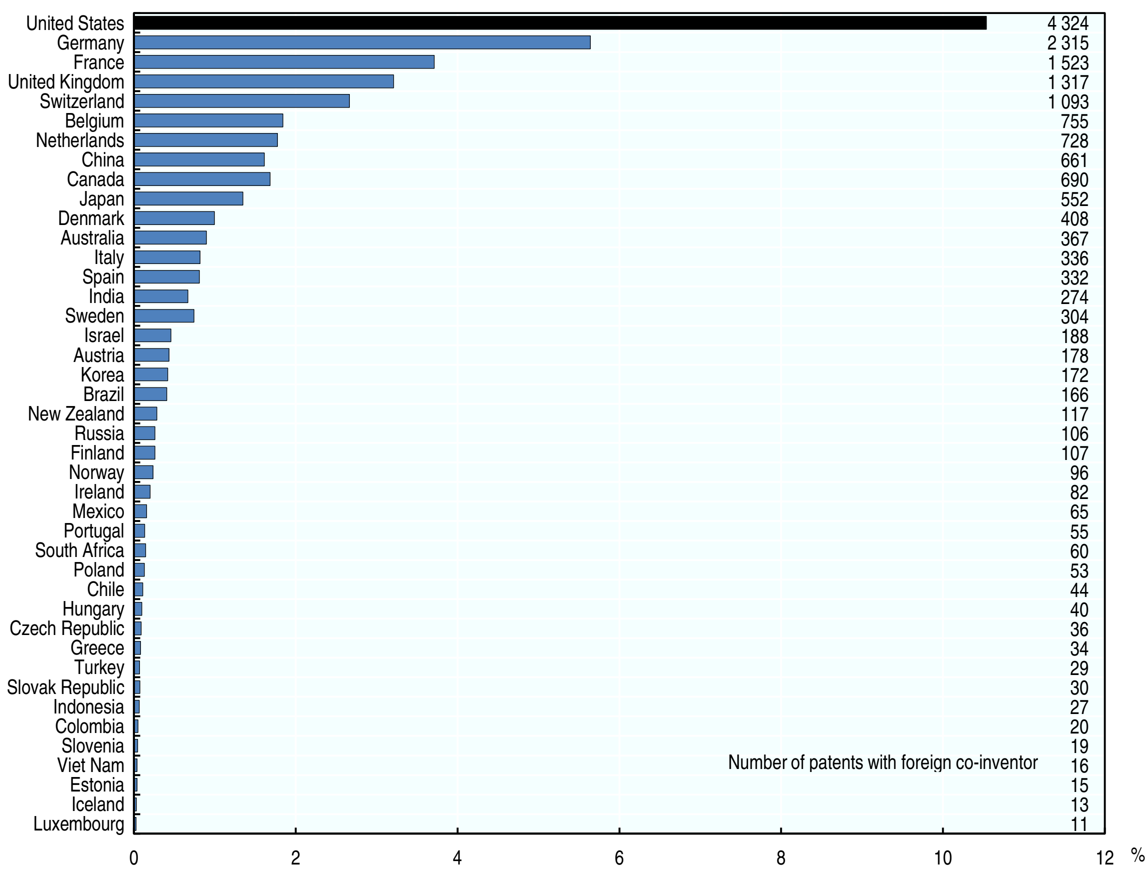
	United States	Australia	Brazil	Canada	Netherlands	EU15 average	OECD average
Patents	14.3	23.1	29.7	29.7	27.1	36.2	11.8
Publications[1]	36.4	47.3	22.3	48.9	65.1	5.7	50.8

1. 2007-12.

Source: OECD Patent Database, January 2014; SCImago. (2007), www.scimagojr.com.

Figure 7.29. Agriculture patents with a foreign co-inventor filed under the Patent Co-operation Treaty (PCT), 2006-11

Country share of agriculture patents with foreign co-inventor as a % of world total



Agriculture includes patents from IPC classes A01, A21, A22, A23, A24, B21H 7/00, B21K 19/00, B62C, B65B 25/02, B66C 23/44, C08b, C11, C12, C13, C09K 101/00, E02B 11/00, E04H 5/08, E04H 7/22, G06Q 50/02.

Patent counts are based on the priority date (first filing of the patent worldwide), the inventors country of residence, using fractional counts. EU28 and BRIICS totals exclude intra-zone co-operations.

Source: OECD Patent Database, January 2014. www.oecd.org/sti/inno/oecdpatentdatabases.htm.

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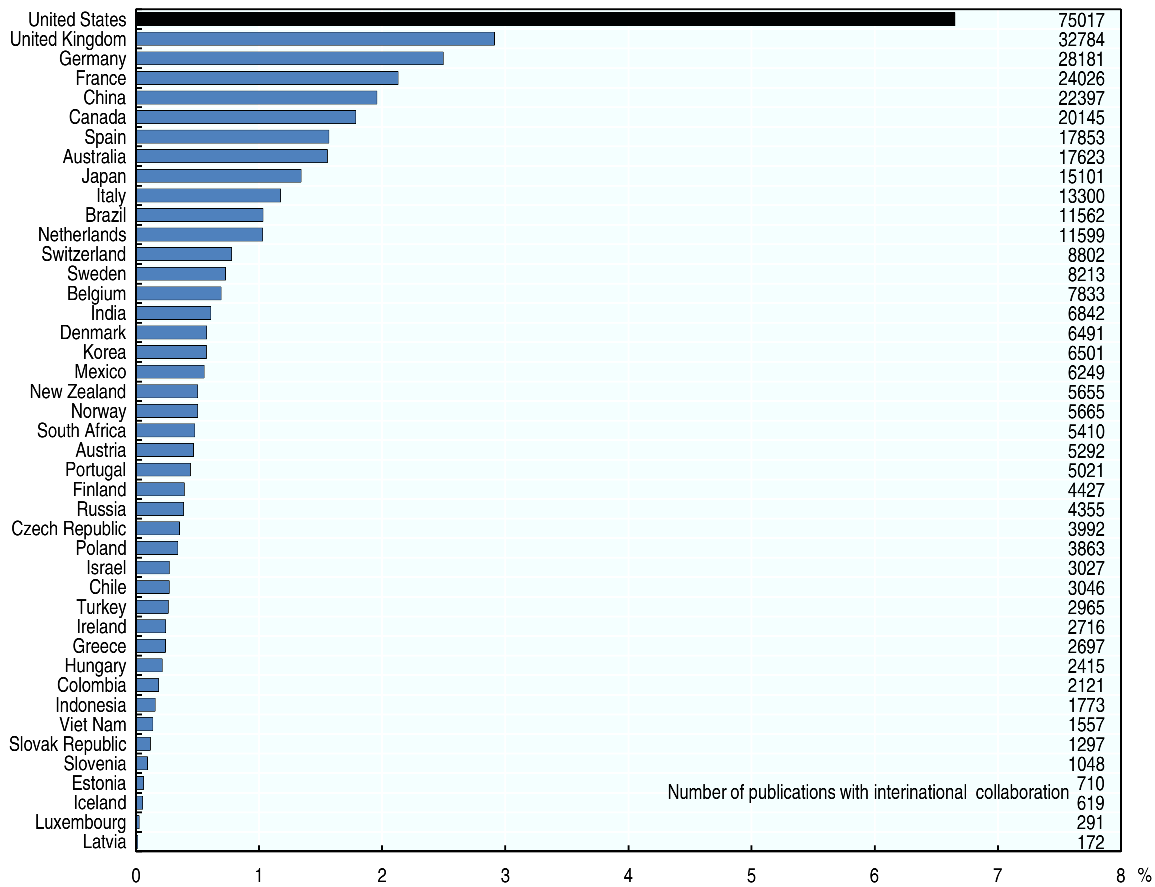
Figure 7.30. Agriculture publications in collaboration, 2007-12

Country share of agriculture publications with foreign co-authors as a % of world total agriculture publications



Agriculture publications include agricultural sciences and food sciences.

Agricultural sciences include Scopus journal classifications: agronomy and crop science, animal science and zoology, aquatic science, ecology/evolution/behaviour systematics, forestry, horticulture, insect science, plant science and soil science, and miscellaneous agriculture/biological sciences.

Source: SCImago (2007), *SJR — SCImago Journal & Country Rank*, Retrieved March 2014, from www.scimagojr.com.

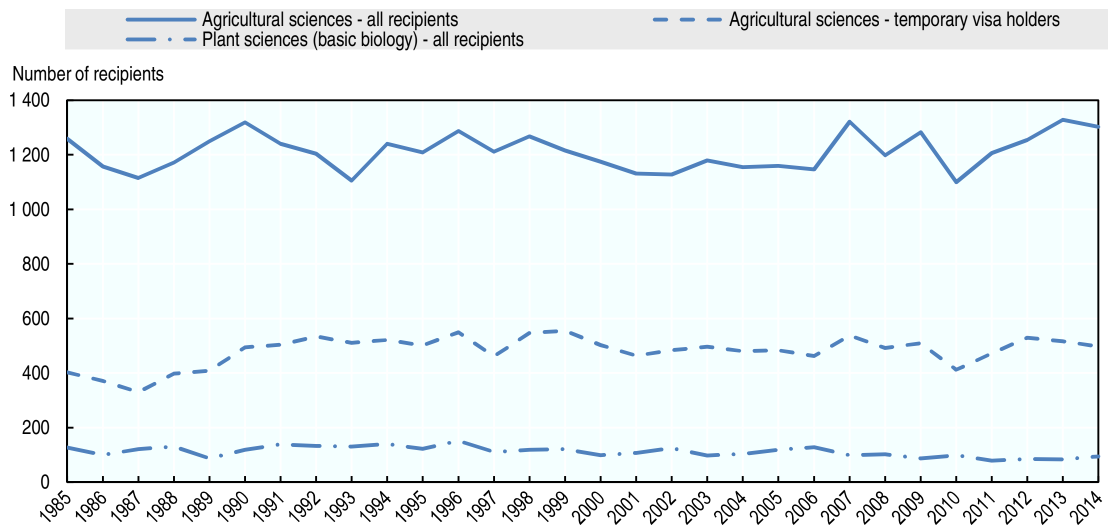
StatLink http://dx.doi.org/10.1787/888933409147

Agricultural universities and training of foreign agricultural scientists

Each year, US universities award about 1 200 doctoral degrees in agricultural sciences (Figure 7.31). About 40% of these are to non-resident foreign students, most of whom return to their home countries following graduation. Over the last 30 years there has been a gradual shift in the composition of Ph.D. degrees awarded in the agricultural sciences. In the 1990s about half of all agricultural science Ph.D.'s were in plant or animal sciences; that proportion has fallen to about one-third. A growing share of agricultural science degrees are being awarded in natural resources (including forestry, fisheries and wildlife).

While the number of doctoral degrees awarded in agricultural sciences has remained fairly constant over the past three decades, the number of Ph.D. degrees awarded in life science disciplines has soared. Between 1984 and 2014, the number of doctoral recipients in life science disciplines increased from 5 800 to 12 500 (National Science Foundation, 2014). Much of this growth was driven by a substantial increase in US Government funding for human health research over this period (see below). Included in life science disciplines (but not classified as agricultural sciences) is a growing number of Ph.D.'s awarded to US and foreign nationals in basic biological and biotechnology sciences, including the fields of plant genetics, plant pathology, and plant physiology (Figure 7.31). Some of the Ph.D. graduates in biological sciences can be expected to pursue careers in agriculture and agricultural biotechnology.

Figure 7.31. Number of doctoral degrees awarded in agricultural sciences by US universities, 1985-2014



Source: National Science Foundation (2016). www.nsf.gov/statistics/2016/nsf16300/digest/.

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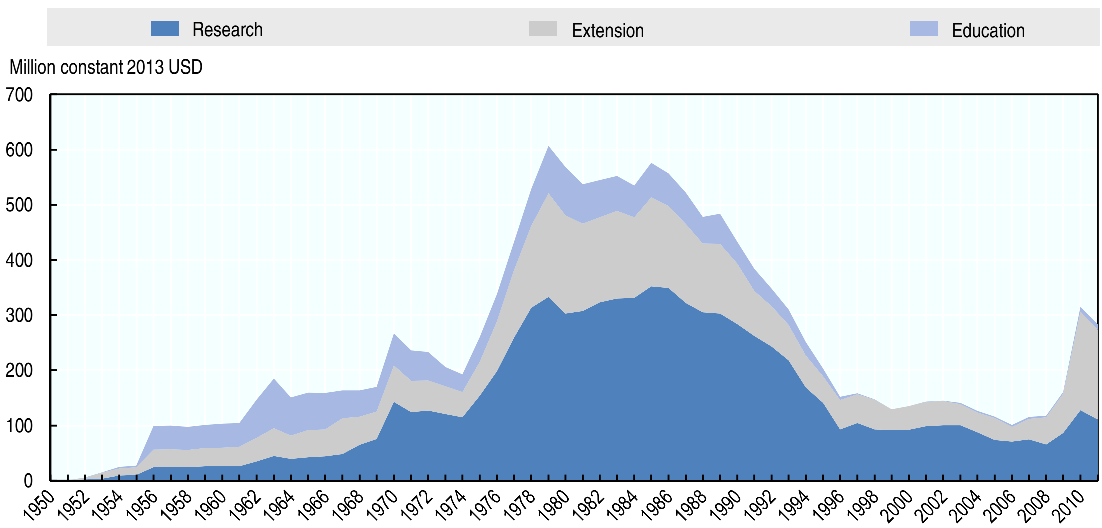
Foreign development assistance for agricultural science and technology

Ever since President Truman' *Point Four Program*, the US Government has offered significant scientific and technical assistance to developing countries. Agriculture has been a major part of this assistance. Funding to support Agricultural Innovation Systems, which includes agricultural research, extension and education, rose rapidly in the 1960s and 1970s, peaking in 1979 at around USD 600 million in 2013 USD (Figure 7.32). Agriculture's role in US foreign assistance diminished in the 1990s, but was reinvigorated through the *Feed the Future Initiative* of the Obama Administration. The *Feed the Future Initiative* is a whole-of-government approach that coordinates activities of several federal government agencies. Since the launching of *Feed the Future Initiative* in 2010, funding for agricultural innovation increased from around USD 100 million to about USD 300 million per year. The US Agency for International Development (USAID) channels funding for agricultural research projects through US universities, national agricultural programmes in developing countries, the CGIAR Consortium of international agricultural research centres, USDA research agencies, and other partners. In 2016, the US Congress passed the Global Food Security Act to establish the *Feed the Future Initiative* as a permanent part of US foreign assistance.

The United States has historically been the largest single donor to the CGIAR since its inception in 1972. In 2014, US contributions to the CGIAR totalled USD 130 million, or 12% of total CGIAR funding (CGIAR, 2014). The CGIAR Consortium includes 15 independent research centres dedicated to improving agriculture, nutrition, and natural resource management in developing countries. In its early years, most CGIAR efforts on crop improvement were focused on Asia and Latin America. Major impacts were achieved through the development and diffusion of high-yielding "Green Revolution" varieties of rice, wheat and maize. Increasingly, the CGIAR has turned its attention to Sub-Saharan Africa, where about half of its research activities are currently oriented

(CGIAR, 2014). By 2010, improved crop varieties had been adopted on 35% of the total area planted to 20 major food crops in Sub-Saharan Africa, with CGIAR Centres contributing about two-thirds of these improvements (Walker et al., 2015).

Figure 7.32. US foreign assistance for agricultural research, extension and education, 1950-2011



Source: Gary Alex, USAID, personal communication (Alex, 2016).

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New initiatives in international cooperation: The G20 MACs and the Global Alliance for Climate-Smart Agriculture

Heightened concerns about the state of global food supply-and-demand balances and the potential effects of climate change on agriculture have led the US Government to strengthen international scientific cooperation in agriculture. In 2012, the Agricultural Ministers of the world's 20 largest economies (the G20) endorsed intensified collaboration in agricultural research amongst their respective countries in order to raise productivity in agriculture. Since 2012, the agricultural chief scientists of G20 nations have meet annually to discuss and explore exploring new mechanisms for undertaking collaborative research on priority topics of mutual interest.

At the United Nations Climate Summit 2014, the United States joined 46 other countries and organisations in forming the Global Alliance for Climate Smart Agriculture. The goal of the Alliance is to develop and promote agricultural production systems that sustainably increase productivity and resilience. A major focus of the Alliance is to increase research and development of new farm technologies and practices that will help farmers deal with the heightened risks associated with climate change.

Information sharing

The US government is committed to the sharing of information from publically-funded research, and promotes the sharing of agricultural research-related information at the international level. Box 7.4 presents the example of the US National Plant Germplasm System, which collects and distributes crop genetic resources from and to different sources, including non-US ones.

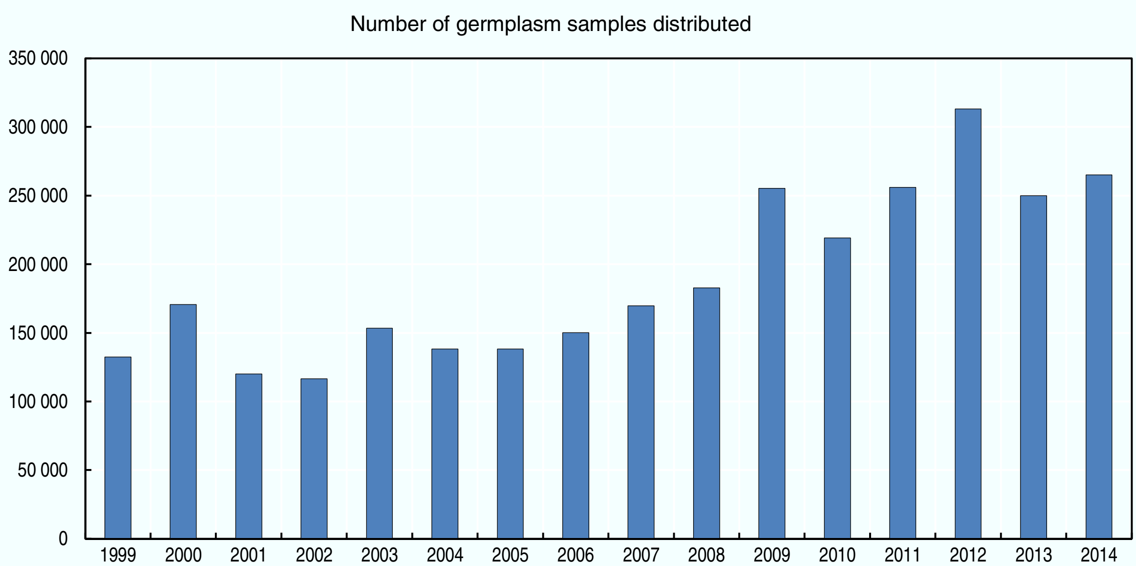
As a G8 member and as part of the New Alliance for Food Security and Nutrition, the United States committed to "share relevant agricultural data available from G8 countries with African partners and convene an international conference on Open Data for Agriculture, to develop options for the establishment of a global platform to make reliable agricultural and related information available to African farmers, researchers and policymakers, taking into account existing agricultural data systems." This led to the creation of the Global Open Data for Agriculture and Nutrition (GODAN) initiative in 2013. GODAN seeks to support global efforts to make agricultural and nutritionally relevant data available, accessible, and usable for unrestricted use worldwide. The initiative focuses on building high-level policy and public and private institutional support for open data.

Box 7.4. Conserving and sharing crop genetic resources

Crop breeders need to have access to a wide diversity of genetic resources to make steady improvements to cultivars, including building their tolerances to biotic and abiotic stresses. The US National Plant Germplasm System (NPGS) is a collaborative effort managed by the USDA's Agricultural Research Service to safeguard the genetic diversity of agriculturally important plants. The NPGS mission is to acquire, conserve, evaluate and characterise, and distribute crop genetic resources. The NPGS has extensive holdings of crop genetic resources, called accessions, which it maintains in gene banks. Many NPGS gene banks are located at state land-grant universities, which contribute field, greenhouse, and laboratory space for operations. The NPGS freely distributes crop germplasm accessions and information about them to researchers, breeders, and educators. It serves a large international scientific community. Requests for materials from the NPGS system has been rising, with over 300 000 crop accessions distributed in 2014 alone (Figure 7.33).

Like all countries, the United States depends on genetic material that is not incorporated into its own gene banks or found within its borders, and thus the NPGS regularly exchanges materials with other institutions. National working groups of specialists familiar with a given crop, called Crop Germplasm Committees, identify gaps in NPGS collections and develop proposals for filling those gaps. For a number of reasons, which may include both the greater codification of rules for germplasm exchange and for intellectual property protection (as well as the fact that many large genetic resource collections have already been transferred from gene bank to gene bank), the number of accessions transferred to the NPGS from non-US sources in a recent five-year period was only about 8% of what it was in a similar period 30 years earlier. In contrast, in the mid-2000s, the NPGS estimated that it distributed approximately six accessions to other countries for every accession it received.

Figure 7.33. Distributions of crop germplasm by the USDA National Plant Germplasm System, 1999-2014



Source: Bretting (2013). http://escop.ncsu.edu/docs/2013%20NPGCC%20Briefing%20Bretting.pdf.

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Summary

- The US agricultural research and innovation system is the leader in terms of its share of global investment and results. Public and private actors play complementary roles, with public efforts focusing on public good provision such as research with long term effects, natural resources and policy issues. A federal-state partnership supports education, research and extension, which are integrated through the unique Land Grant system. Among government agencies, the Agricultural Research Service (ARS) of the USDA is the main performer of agriculturally-related research.

- The office of the USDA chief scientist coordinates agriculturally-related research across the USDA and other federal government agencies, through participation in science and innovation coordination bodies. Government also receives advice from national academies. Stakeholders inform and influence priorities through formal mechanisms such as membership to a national advisory board, and *ad hoc* consultations when planning major programme activities.

- With the emergence of stronger linkages between agricultural sciences and other fields, especially biological sciences and information technologies, the set of institutions funding and preforming research relevant to agriculture has broadened.

- Government research programmes are evaluated annually and at the end of five-year cycles, providing useful information for the next cycle. Evidence of widespread adoption of some innovation is well-documented and analysed.

- Private expenditure on food and agriculture R&D nearly doubled in real terms between 2003 and 2013, while public expenditure declined. Federal expenditure now accounts for 17% of the total and the combined share of federal and state expenditures does not reach 25% of total.

- Agriculturally-related research alone was traditionally dominated by the public sector but private expenditures have overtaken public expenditures since 2011.

- Mechanisms to fund research have evolved. Main funding for University-State Agricultural Experiment Stations (LGU-SAES) traditionally came from capacity research grants, with federal-state co-funding. In recent decades, the USDA has given greater emphasis to competitive funding mechanisms, which accounted for half of resources by 2010.

- Federal-state partnerships support education, research and extension, which are integrated through the unique Land Grant system. In addition to advice from input suppliers, public extension services provide a widening range of advice on agriculture, conservation, rural development, health and nutrition through partnerships between federal, state and local governments. As for research, the USDA establishes broad priorities for programmes it co-funds, and state and local partners define priorities for cooperative extension. Over time, the share of federal funding has decreased.

- Intellectual Property is well-protected using a diversity of mechanisms, and thus have encouraged private investment in R&D and adoption of innovation. There is widespread use of patents for transgenic crops, although companies often apply for both patents and Plant Variety Protection Certificates for the same cultivar.

- The Federal Government offers three tax provisions to encourage private firms to engage in R&D: a deduction from taxable income for research expenses, a tax credit for increasing research activities, and an exemption for donations to charitable agricultural research

organisations. In 2015, tax exemptions for charitable agricultural research organisations were created to encourage charitable contributions to agricultural research.

- Direct support to innovation includes grants to private firms engaged in R&D activities, public-private R&D collaboration agreements, and patenting and licensing by public institutions to foster private innovation. In the early 1980s, new legislation encouraged government laboratories to increase cooperation with the private sector; authorised the patenting of publically funded research; and established the SBIR programme, where a minimum percentage of government agency R&D funding is required to be allocated to small businesses. More recently, the Foundation for Food and Agricultural Research was established as a non-profit, non-government organisation to support joint public-private funding of food and agricultural research.

- Scientific publications and patents illustrate the leading role the United States plays in global agricultural science. The number of petition approvals of GE crops submitted to government agencies also illustrates the growing activity of US research in this area.

- Numerous studies of the impact of public agricultural research on the productivity of the entire farm sector show significant and high returns to research (estimates range from 20% to 60% with a median of 40%), with these benefits lasting for several decades. These studies also found benefits of public agricultural research were widely shared, not only among farmers but also to consumers in the form of more abundant and lower cost food.

- With growing capacities in agricultural science and technology elsewhere in the world, US public research institutions have placed greater emphasis on international collaboration to address shared global challenges. In addition, the United States continues to give priority to investing in agricultural innovation systems to promote food security in low income countries.

Notes

1. The National Academy of Sciences (2009) characterised New Biology as the integration of life sciences with physics, engineering, computational sciences, mathematics and other disciplines. It affords new opportunities for biological research to address pressing societal problems regarding food, the environmental, energy, and health. Adapting crops to changing environments, developing sustainable alternatives to fossil fuels, improving human nutrition, and developing new biomaterials for industry are some of the areas where the New Biology can be applied to agriculture.
2. Box 7.4 in OECD (2015b) discusses the roles of IPR in plant breeding, including in the WTO and developing country context. It suggests ways to amend the patent system to broaden innovation in plant breeding.
3. Only estimates for 1998 are reported to save space; there were not enough operations in the largest class to generate an estimate for 1992, and estimates in 2004 and 2009 changed little.

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