OECD Food and Agricultural Reviews

Innovation, Productivity and Sustainability in Food and Agriculture

MAIN FINDINGS FROM COUNTRY REVIEWS AND POLICY LESSONS

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Please cite this publication as:
OECD (2019), *Innovation, Productivity and Sustainability in Food and Agriculture: Main Findings from Country Reviews and Policy Lessons*, OECD Food and Agricultural Reviews, OECD Publishing, Paris, *https://doi.org/10.1787/c9c4ec1d-en*.

ISBN 978-92-64-87589-0 (print)
ISBN 978-92-64-83391-3 (pdf)

OECD Food and Agricultural Reviews
ISSN 2411-426X (print)
ISSN 2411-4278 (online)

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Foreword

Since 2015, the OECD has published twelve OECD Food and Agricultural Reviews on Innovation, Agricultural Productivity and Sustainability, which were undertaken at the request of and in collaboration with national authorities. These reviews analyse the extent to which the policy environment improves innovation, productivity and sustainability in food and agriculture, using an analytical framework developed to that effect in the course of OECD work for the Committee for Agriculture and the G20.

This report presents the main findings from country reviews and related work on the impact of policies on agricultural productivity and sustainability, comparing the challenges and the policy environment for food and agriculture across reviewed countries. From that comparison, main policy lessons are drawn, illustrated by examples of good practices, which should be relevant for a wide set of countries.

Chapter 1 provides a stand-alone synthesis of the main findings from country reviews and related work. Chapters 2 to 7 contain more detailed, comparative information. Chapter 2 provides an overview of main productivity and sustainability challenges for food and agriculture in reviewed countries. Chapter 3 summarises findings on drivers of productivity and sustainability: innovation, structural change, and natural resource use and climate change. Chapters 4 to 6 discuss the extent to which agricultural policies, policies relating to the innovation system and the wider policy environment respectively facilitate innovation, productivity and sustainability in food and agriculture, and provide recommendations in these policy areas. Chapter 7 concludes with a discussion of policy coherence issues. Annex A contains the definition of concepts and indicators used in the report. Annex B contains an overview of reviewed countries, which contrasts their geographical and economic situation and the main characteristics of their food and agriculture system, including additional information on trends in agri-environmental performance. Annex C contains country-specific information on main opportunities and challenges for the national food and agriculture, and key recommendations for each policy area corresponding to main findings on policies in place as specified in their respective reviews.

This review was prepared by Catherine Moreddu and Guillaume Gruère, with contributions from Morvarid Bagherzadeh, Dimitris Diakosavvas, Emily Gray, Shingo Kimura and Urszula Ziebinska. It also benefited from comments from other colleagues in the Trade and Agricultural Directorate and from countries' delegates to the Working Party on Agricultural Policies and Markets. Martina Abderrahmane provided editorial assistance.

This document was declassified by the Working Party on Agricultural Policies and Markets on 25-26 March 2019.

Table of Contents

Tables

Figures

Boxes

Key findings

A wide range of policies affect innovation, productivity and sustainability in food and agriculture. The following policy lessons emerge from a series of OECD and G20 country reviews on ways to improve the long-term productivity and sustainability performance of the food and agriculture system.

- The whole policy package matters: improving policy coherence and transparency is crucial to increasing policy effectiveness, trust, and efficiency in the agro-food sector.
- Policy strategies should cover the whole food supply chain, as productivity and sustainability need improvement along the chain and participants need to work together.
- There is a business case to innovate and to improve productivity and environmental performance, from farm to fork. Well-functioning markets and a sound regulatory and policy environment are key to harnessing evolving market opportunities.
- The first step to improving the policy environment is to roll back policies that keep farmers in uncompetitive and low-income activities, harm the environment, stifle innovation, slow structural and generational change and weaken resilience. Agriculture policy should then focus on measures to improve the sector's long term productivity and sustainability.
- The governance of national agricultural innovation systems needs to be improved; for example, establish a long-term strategy, consult stakeholders early and often, clarifying the role of different organisations, improve co-ordination across research and other organisations, and implement comprehensive evaluation systems.
- It is important to strengthen linkages within the agricultural innovation system, between research and development (R&D) and technical assistance, and with R&D in other sectors, for example by enabling research co-operation and participation in networks.
- Public funding of agricultural R&D is crucial. It should provide stable funds for knowledge infrastructure, strengthen the research with public good aspects, and complement private research efforts.
- Governments should help strengthen private funding for R&D and foster public-private partnerships to increase the impact of public funding, for example by enforcing intellectual property rights and targeting support to innovation in areas where there is under-investment.
- Governments should also facilitate international co-operation on R&D and innovation, for example by encouraging staff and student exchanges, sharing research infrastructure, and supporting participation in international projects and networks.

- Governments should ensure farm advisory and extension systems include a diversity of competitive public and private providers to address constraints on technology adoption, from managing farm and natural resources management to coping with climate change.
- Better information and analysis is needed to support government decision-making and to improve policy performance. It can also contribute to improving communication to foster acceptance of reform and of innovation.

Chapter 1. Main policy lessons from selected country reviews

This chapter offers an overview of main policy lessons from country reviews and related work on ways to improve the long-term productivity and sustainability performance of the food and agriculture system. Following a brief presentation of the framework used as a basis for the country reviews and a summary of the main productivity and sustainability challenges faced by the twelve reviewed countries, the chapter outlines the key policy recommendations in the different policy areas covered in the reviews. Finally, knowledge gaps are identified and ways to improve the relevance of the reviews are discussed.

Strengthening the long-term performance of food and agriculture

Developing policies to underpin competitive, sustainable, productive and resilient farm and food businesses is a high priority for OECD and G20 governments.[1] In 2016, Ministers of agriculture of OECD countries recognised "…the need for integrated policy approaches that will better enable farmers and the food sector to simultaneously improve productivity, increase competitiveness and profitability, improve resilience, access markets at home and abroad, manage natural resources more sustainably, contribute to global food security, and deal with extreme market volatility, while avoiding trade distortions." (OECD, 2016a). They invited the OECD to pay urgent attention to analysing the policy environment for food and agriculture in this context.

Since the mid-1980s, agricultural policy reforms in OECD and key emerging economies have reduced distortions to markets and trade: support levels have generally decreased and there has been a shift towards measures having less impact on producer decisions and, in some cases, target policy objectives more precisely (OECD, 2018a). However, progress has been unequal across countries. A large part of support to agriculture continues to support farm income, irrespective of actual levels and without setting specific targets. Many countries use commodity-specific measures, which are not efficient at transferring income or meeting other productivity-sustainability objectives. Thus, current policies are generally not well-aligned with policy objectives.

A more efficient approach would be to focus agricultural policy on measures that strengthen the long-term productivity[2] and sustainability[3] performance of the sector (OECD, 2018a). These include investments that improve innovation[4] and infrastructure capacity, and farmer access to input and output markets. Strengthening the long-term performance of food and agriculture would also require adopting integrated policy approaches that encompass the wider enabling policy environment.

A framework to review policies affecting the food and agriculture sector

A wide range of policies affect food and agriculture performance. Thanks to the increasing number of policy evaluation requirements that are imposed in many countries, significant progress has been made to date in understanding the impact of agriculture-specific policies. However, the impact of general policies on the economic and environmental performance of the agricultural sector has received less attention. Yet, establishing synergies between policy areas, as well as avoiding overlaps and contradictory policy signals, are clearly important for achieving the twin goals of a more productive and a more environmentally sustainable food and agriculture sector.

The OECD has developed the "Food and Agriculture Productivity-Sustainability Framework" to help countries adopt a more enabling policy environment for food and agriculture (Box 1.1). This framework identifies innovation, structural change, natural resource use, and climate change as the drivers of productivity and sustainability and considers the main channels through which policy incentive areas affect these drivers.

Box 1.1. The Food and Agriculture Productivity-Sustainability Framework

This framework considers the full range of policy incentives and disincentives to innovation, structural change, natural resource use, and climate change, all of which have been identified as drivers of productivity growth and the sustainable use of resources (Figure 1.1).

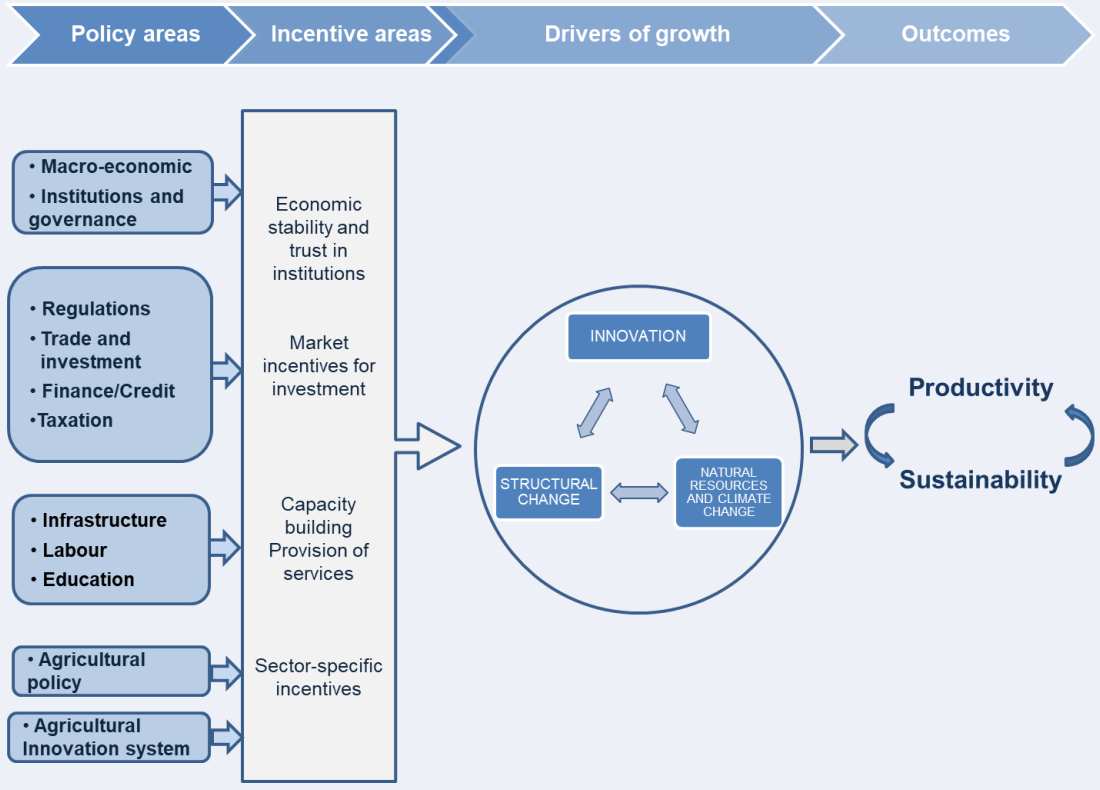
The main channels, or incentive areas, are the following:

- Economic stability and trust in institutions (macro-economic policy, justice, security, property rights), which are essential to attract long-term investment in the economy.
- Private investment, which in turn requires a transparent and predictable environment that balances the interests of investors and of society. The regulatory environment for businesses, natural resource use, and farm inputs and food products and policies related to trade and investment, finance and credit, and taxation have a direct impact on investment in agricultural and food companies.
- Physical and human capacity building enables the provision of essential public services and the development of skills needed in food and agriculture. Capacity building is influenced and affected by infrastructure, rural development, labour, and education policies.
- Agriculture-specific policies, which provide direct incentives and disincentives to innovation, structural change and natural resource use in agriculture. They include market price support measures, input subsidies, direct payments to producers, and various services to producers and the sector. Within policies that provide services, the agricultural innovation system receives special attention. It provides continuous innovation in technologies, practices, and organisation that facilitate the development of a more productive and environmentally sustainable food and agriculture sector.

Drivers interact with each other: some innovations (e.g. labour saving ones) facilitate structural adjustment, and structural adjustment facilitates the adoption of scale-dependent innovations. Natural resource constraints foster the adoption of innovation (e.g. drought-resistant seeds), which help improve sustainable resource use and adaptation to climate change.

The role of innovation and structural change in productivity growth is well-established in the theoretical and evidence-based literature. At the firm level, productivity growth has three components: 1) technological progress reflects early adoption of innovation by best performers; 2) technical efficiency change represents wider diffusion of innovation; and 3) economies of scale represent a movement along the efficiency frontier due to a change in firm size (OECD, 2011a; Latruffe, 2010). Structural change also affects the capacity to adopt scale-dependent innovations. Many if not most agricultural innovations result from formal public and private investments in agricultural research and development (R&D); in turn, many studies find a long-term positive impact of agricultural R&D on productivity growth. Moreover, productivity growth is often used as an indicator of research or innovation impact.

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



Source: OECD (2015a), "Analysing Policies to improve agricultural productivity growth, sustainably: Revised framework", www.oecd.org/agriculture/topics/agricultural-productivity-and-innovation/documents/analysing-policies-growth-2015-draft-framework.pdf.

Since 2015, the OECD has undertaken 12 in-depth country reviews using this framework.[5] Parts of the framework have also been used in reviews of agricultural policies in Argentina, Colombia and Switzerland. The countries reviewed differ in their economic and environmental conditions, policy frameworks, and performance of their food and agriculture sector. The reviews identify the extent to which countries' policy settings have been addressing productivity and sustainability challenges, if and how they have realised developments towards achieving both, or where they have put more implicit or explicit weight on one of the two objectives. These reviews reflect positively on the relevance of the framework to analyse the policy environment for food and agriculture in a wide range of countries.

Various OECD studies provided analytical support to the reviews, notably those on agricultural innovation systems, drivers of productivity growth, and green growth in the food and agriculture sectors. In addition, analyses were conducted in parallel in order to shed light on specific issues, such as taxation policy in food and agriculture, drivers of farm-level performance, the impact of agricultural policy on farm productivity and sustainability, digital opportunities for agriculture, strengthening agricultural resilience in the face of multiple risks, and on how to meet labour and skills demands, particularly in rural areas.

The reviews reveal gradual, but significant improvements in the policy environment for food and agriculture, although progress has been unequal among reviewed countries and among policy areas. In many countries, the existing policy environment continues to impede innovation, adjustment, the sustainable use of resources, as well as better adaptation to climate change. Diverse types of policy incoherencies slow down efforts towards a more productive and sustainable agriculture.

The reviews, however, highlight common solutions to developing and implementing policies that improve productivity and sustainability in food and agriculture. The comparison of reviews further suggests that countries would gain from learning from each other's experiences, both positive and negative.

Further productivity and sustainability improvements are needed in food and agriculture

All countries reviewed face challenges with respect to the productivity and sustainability in food and agriculture, and they will need to address these challenges jointly in order to respond to changing demands, to generate adequate income for farming families, and to contribute to the rural economy (Table 1.1).

The productivity performance of primary agriculture is contrasted across reviewed countries. Total factor productivity (TFP) growth, as estimated by the United States Department of Agriculture (USDA), ranged from 1% to over 3% per year on average over the period 2001-14 (Table 1.2). In countries with an annual TFP growth below 2% on average, performance has declined compared to that of the previous decade. In contrast, significant improvements have occurred since the period of 1991-2000 in countries which registered a TFP growth over 2% over 2001-14. There are also large differences in productivity growth by commodity sector (e.g. between soybeans and other products in Argentina), farm size and regions. In Estonia and Korea, several of the larger farms drive national productivity growth. Sustainability challenges, including the availability and quality of land and water, already constrain productivity growth in some countries.

Improving productivity growth further remains a challenge both in highly performing countries, where easy adjustments have already occurred, and in less performing ones where changes in incentives and disincentives are needed. In many countries, the lack of competitiveness and capacity in food processing industries is an issue for at least some part of the sector, limiting the expansion of agriculture, innovation and export capacity in the food system. Improvements are thus needed along the value chain.

At the farm level and along the value chain, improving the measurement of productivity would help to better understand the potential issues and to identify appropriate actions. Yet the measurement of TFP remains a challenge, given the different methods used and data limitations. These difficulties increase when attempting to incorporate environmental performance in TFP, as the quality and availability of the information also remain a limitation.[6]

Table 1.1. Summary of main challenges for food and agriculture

	Structural challenge	Productivity challenge	Sustainability challenge	Climate change challenges and opportunities
Argentina	Investment in rural and transport infrastructure	Regional and product differences in productivity growth	Deforestation, increased use of inputs affecting water and air quality	Increasing frequency of extreme weather events, melting of glaciers
Australia	Increasing differences between small and large farms. Remoteness of some farms	Availability of new technology. Drought and water shortages constrain productivity growth	Water and soil constraints, Greenhouse Gas (GHG) emissions	More severe water constraints
Brazil	Dualistic structure	Large productivity gap between subsistence and commercial farms	Land management, GHG emissions	Not included in the review
Canada	Production quotas, weak food industry, and small domestic market	Mainly in the dairy sector	Land management affecting biodiversity, regional water quality issues from excess nutrients	Better growing conditions in some regions, increased frequency of extreme weather events (floods, droughts), potential increase in pest and disease
China	Small farms dominate Income gap between rural and urban households	Water resource constraints, small farms	Water resources constraints, pollution of soils and water, and expansion of intensive livestock production	Rising temperatures, more frequent extreme weather events, spread of pests and disease
Colombia	Small, subsistence farms	Large differences by commodity sector. Low productivity in dairy farms due to small scale, high input prices, poor transport infrastructure and inefficient value chain	Land management affecting biodiversity, GHG emissions, and intensive use of inputs	Rising and more erratic precipitations causing soil degradation. Rising temperatures requiring moving production in higher altitudes (Coffee). Melting of glaciers and disappearance of moorland
Estonia	Dualistic structure	Productivity driven by a small number of larger farms, high growth rates reflecting catch up	Local water pollution by nutrients	Better growing conditions despite potential increase in pests and diseases, and rainfall variability
Japan	Increasing differences between small and large farms	Labour shortages and ageing	High nutrient surplus driven by intensive use of fertiliser, GHG emissions	Increased frequency of extreme weather events (typhoons)
Korea	Small farms dominate Income gap between rural and urban households	Productivity gap with manufacturing sector, small farms	High nutrient surplus. Expansion of intensive livestock production, increasing nutrient surplus and GHG emissions	More typhoons; more erratic monsoons; warming in the South
Latvia	Dualistic structure	Productivity driven by a small number of larger farms, high growth rates reflecting catch up	Local water pollution by nutrients	Better growing conditions, increase in pest and disease, and rainfall variability
Netherlands	High land prices	Sustain growth with higher constraints	Water pollution by nutrients; GHG emissions and biodiversity	Increased frequency of extreme weather events, Water management
Sweden	Areas with natural handicaps (northern latitudes)	Low and declining growth rate for some sectors	Eutrophication, biodiversity and GHG emissions	Better growing conditions, prolonged cultivation period, climate favourable to other crops
Switzerland	Areas with natural handicaps (mountains)	Low and declining growth rate	Nitrogen surplus does not meet country targets	--
Turkey	Large number of small farms	Productivity gap between small and larger farms	Water scarcity, water quality and soil erosion	Increased water stress and temperature increase affecting agriculture
United States	Labour shortage	Declining growth rate	Water scarcity, pollution and soil erosion, particularly in certain regions	Higher frequency of extreme weather events, higher water constraints in some regions

Source: OECD country reviews.

In most reviewed countries, structural challenges remain, as smaller and less productive farms continue to co-exist with larger operations. In some, small farms account for a large part of land use and production, while in others, they co-exist with very large farms, which dominate production in a dualistic structure, with increasing differences in performance between small and large farms. Structural challenges also include labour shortage and weaknesses in infrastructure, particularly in remote areas, as well as areas with natural handicaps (mountains or northern latitudes).

Table 1.2. Total Factor Productivity growth

Annual percentage growth, 1991-2000 and 2001-14

	2001-14	Increase compared to 1991-2000	Decrease compared to 1991-2000
<1.0%			
1.0-1.5%	Australia, Colombia, Sweden, Switzerland		Australia, Colombia, Sweden, Switzerland
1.5-2.0%	Canada, Korea, United States, EU28, OECD	EU28, OECD	Canada, Korea, United States
2.5%	Turkey	Turkey	
2.5-3.0%	Japan, Netherlands, Brazil, Latvia	Japan, Netherlands, Brazil, Latvia	
>3.0%	China, Estonia	China	

Notes: 1. EU28 and OECD averages. 2. 1991-2000 data are not available for Estonia and Latvia.
Source: USDA (2018), Economic Research Service, International Agricultural Productivity, www.ers.usda.gov/data-products/international-agricultural-productivity.aspx (accessed October 2018).

Despite a wide diversity of situations, environmental pressures are increasingly decoupled from agriculture productivity trends (Table 1.3), i.e. while agricultural productivity grows, environmental damages decrease or increase at a slower rate in many countries. Sustainability issues affect most countries but differ in terms of nature and extent between and within countries. In some countries, water scarcity is the main problem, while in others it is pollution from nutrients. Progress has been observed at least in some dimensions of agriculture sustainability in all reviewed countries, even if environmental pressures remain high. In most countries, the percentage change in agriculture's negative impacts on the environment have not exceeded the percentage change in productivity gains (thereby experiencing relative environment decoupling), with some countries even reducing negative impacts while increasing productivity (absolute environment decoupling).

Table 1.3. Decoupling agriculture productivity from resource and environmental pressure: Observed trends

Based on average annual change between 1998-2000 and 2010-12[1]

	Resource	Environment
Absolute decoupling	Water use: Australia, Estonia, Korea, Netherlands Land use: Korea, Netherlands	Nitrogen and Phosphorous balance: Estonia, Sweden, Turkey, United States Ammonia: Netherlands, Sweden, United States Greenhouse gas (GHG) emissions: Netherlands, Turkey Pesticide sales: Netherlands, Korea, United States; Pesticide risk: Sweden
Relative decoupling	Water use: China, Turkey, United States Energy use: Estonia, United States	GHG emissions: Estonia, United States
Deterioration	Energy use: Turkey	Pesticide sales: Turkey GHG emissions: Korea

Notes: 1. Time periods are not identical for each country, more recent date on agri-environmental indicators might alter this assessment. 2. Absolute decoupling refers to a situation in which resource impacts decline in absolute terms. 3. Relative decoupling refers to a decline in the ecological intensity per unit of economic output.
Source: Adapted from country reviews.

Climate change will modify the natural conditions for agriculture and increase uncertainties everywhere. Northern countries will enjoy better growing conditions that increase productivity, but higher temperatures may also result in an increase in pest and diseases. More extreme weather is expected, and water management will become more challenging in most countries. This will affect the range of climate-adapted products, and thus productivity, and the type and degree of stress from water, heat, pests and disease, so adaptation is crucial. Efforts to mitigate climate changes through reductions in greenhouse gas (GHG) emissions from agriculture will also constrain production.

Removing policy distortions and regulatory impediments along the value chain

First and foremost, existing policies that deter agricultural productivity and sustainability should be removed. This will prevent inconsistent policy signals and the creation of further complexities into policy making. The main areas for policy improvement include agricultural markets, land markets, water management, and enforcement of property rights. Access to competitive inputs and services also need to be improved in many countries.

Remove support that most distorts agricultural commodity markets

The most distorting forms of support from agricultural policies should be eliminated, as they encourage the sub-optimal and unsustainable use of resources and production choices. These include border measures and domestic policies that raise prices and receipts received by producers above world levels, and measures that reduce the cost of variable farm inputs without imposing environmental constraints. Reducing support levels and differences in support level across commodities would also enhance the reallocation of resources towards more efficient uses based on market demand. In particular, the provision of coupled payments that enhance commodity production and distort allocation of resources across commodities should be limited to well-targeted measures.

Australia provides an example of a country where agricultural policy distortions are minimal: support to agricultural producers is one of the lowest amongst the reviewed countries; domestic prices are fully aligned with international prices and producer support measures mainly focus on facilitating risk management and adaptation. Moreover, about half of Australian support to the agricultural sector funds general services, in particular agricultural innovation systems and rural infrastructure which foster long-term improvements in productivity and sustainability. Successive droughts and water shortages have, however, limited productivity growth since 2000.

Since the mid-1990s, there have been significant reductions in distortions in EU Member States, Switzerland, and the United States, resulting from lower support levels and the introduction of payments to producers that are not based on production criteria or do not require production to replace former coupled support. While these decoupled payments are much less distorting than coupled support, they allow maintaining land in non-productive uses and slow structural adjustment, thus affecting productivity growth.

Other impediments to innovation, structural change, and sustainable resource use should be removed. For example, support that provides higher benefits (or impose lower tax rates) to smaller farms or firms can slow adjustment towards more productive production scales, and thus may discourage them to develop their activities for fear of losing these benefits.

In some countries, support to farmers is conditional on the adoption of environmentally-friendly production systems. This has had positive impacts on sustainability, but requirements should not discourage innovation and adaptation to local conditions.

Improve the functioning of input markets

Impediments or disincentives to structural adjustment and the realisation of scale economies may exist in the land and labour markets. In Asian countries, land scarcity and restrictions on land use and markets have hindered the adjustment needed to improve productivity and sustainability. Efforts are being made, however, to improve the functioning of land markets, in part to respond to the shortage of labour in the sector. For example, the People's Republic of China (hereafter "China") implemented measures to facilitate land consolidation. While promoting flexible formats for consolidated farm operations, the government supports the development of co-operatives as a new type of farm management unit, using preferential tax treatment.

Ensuring that the supply of labour meets the demand of the food and agriculture sector is a widespread issue, as is adapting skills to changing needs. In response to seasonal labour needs, most of the countries reviewed with the exceptions of Argentina and Brazil have less protective regulations on temporary forms of employment than on regular employment. The reviewed countries have implemented specific provisions for seasonal immigration, which makes up a significant part of seasonal labour. These provisions include temporary immigration schemes that allow employers to hire foreign nationals when qualified citizens are not available (Canada, Korea, and the United States), schemes that provide sponsorship of employers for foreign workers, including skills training components (Australia), regional programmes to attract newcomers to regions with shortages, and the removal of impediments regarding labour costs for employing foreign workers (Estonia). In Sweden, in addition to incentives that promote employment in the green industries (e.g. forest) for newly arrived individuals, the 2017 Food Strategy emphasises the need to accelerate labour adjustment for both the agriculture and food sector.

To reduce labour shortages, it is also important to ensure that taxation is not so high that it discourages participation in labour markets, in particular for low-cost jobs in food and agriculture, and to ensure legislation and tax provisions do not impede farm transmission.

Several of the reviewed countries have recently introduced promising programmes or regulations to improve their management of water resources, with a particular emphasis on agriculture. For example, Brazil has initiated steps to bolster the use of water charges for hydropower facilities and agriculture users. These water charges aim to help improve water allocation while helping to recover regulatory agency recover charges.

A well-functioning financial market facilitates access to finance for farmers and agri-food firms. Many countries provide investment support to farms and food processing firms, but it would be more efficient to address the causes for the lack of access to credit at market conditions (e.g. by addressing market failures, facilitating collaterals, or improving risk management).

Finally, an effective competition policy, including low barriers to entry and exit, facilitates access to a diversity of affordable inputs for farmers and to food for consumers. Competitive conditions also encourage innovation and productivity growth, including through their impact on structural change along the value chain. Business regulations have generally become more supportive of innovation over time. In particular, starting a business has become easier in many countries, thus improving competition.

Reduce barriers to trade

Trade can facilitate the flow of goods, capital, technology, knowledge, and people needed to innovate. In OECD countries, trade policy does not generally restrict access to modern

technologies and farm inputs. Tariffs on capital and intermediate goods are particularly low in Australia, Canada, Japan, and the United States. In emerging economies like Brazil and China, however, these tariffs are higher than in most OECD countries. This increases the cost of capital, inputs and machinery equipment that are needed to innovate, and thus affects the competitiveness of the agri-food sector. In the reviewed countries, some farm sectors are also protected from foreign competition.

Country reviews and accumulated evidence suggests that governments should reduce tariff protection to facilitate trade and investment, as well as to ensure that non–tariff measures do not lead to excessive trade costs, either because regulations are different between countries while aiming at the same regulatory issue or because implementation and conformity assessment are overly burdensome.

Trade facilitation procedures have improved in most of the reviewed countries since 2012, but countries should explore the scope for further trade facilitation, e.g. by using digital technologies. There are few restrictions to foreign direct investment in the reviewed countries, with the exception of agricultural land in a few of them.

Making the agriculture research and innovation system more responsive to needs

Continuous innovation in technologies, practices and organisation facilitate the development of a more productive and environmentally sustainable food and agriculture sector. Research and innovation play a dominant role in driving productivity growth in the short and long term in all the countries reviewed. The theoretical pathways between innovation and productivity are backed by empirical evidence from both sector-level and farm-level estimates. Innovation can also improve sustainability if incentives to that effect are in place. Improving the responsiveness of agricultural innovation systems to needs, and the acceptance of innovation by consumers and society, is thus crucial.

Agricultural innovation systems are diverse

The agricultural innovation system (AIS) is the main vehicle to develop agronomic and technological solutions to improve the productivity and sustainability of food and agricultural production. Encompassing the adoption of these solutions, the system involves a wide range of actors including policy makers, teachers, researchers, advisors and brokers of innovation, farmers, agri-food companies, co-operatives, non-profit organisations (NGOs), and consumers.

AISs in the reviewed countries are very diverse in terms of ambitions, institutional set-up, and funding mechanisms. For example, country reviews cover the two countries that contribute the most to world public investment in agricultural research — China and the United States — as well as small economies with greater reliance on imported knowledge. The contribution of public research organisations under agriculture-related ministries to agricultural research is particularly important in Argentina, Brazil, Colombia, Korea, Japan, and the United States, while that of specialised universities dominate in other countries. Public and private research intensity — expenditure on food and agriculture research as a percentage of the sector's gross-value added — varies significantly across countries as do funding mechanisms, notably the share of project funding in total government expenditure on agricultural research.

Governments traditionally play an important role in agricultural innovation systems

Governments provide strategic guidance, financial support to researchers and advisors in public and private organisations, and research infrastructure such as databases, laboratories and information and communication technologies (ICT). In many countries the public sector dominates agricultural research. Governments also encourage private investment in research and innovation through investment support, tax policy, intellectual property rights (IPR) protection, and more generally policies that enable investment. Governments have traditionally played an important role in organising and financing training and advisory systems, thus facilitating innovation at the farm level, and public systems continue to dominate in some countries.

Agricultural innovation systems are in transition

Changes are in response to the recognition in many of the reviewed countries that new challenges require a different approach to innovation. The main trend in innovation policy is to improve the impact of public expenditure and make the system more collaborative and demand-driven to increase adoption. Despite progress, however, top-down approaches continue to dominate in most countries, although mechanisms are in place to improve responsiveness to needs, as outlined below.

Various trends in public funding for agricultural research are found across countries, depending on the indicator. Government budget allocated to agricultural R&D has decreased in the last 15 years in several major exporting countries like Canada, the Netherlands and the United States, both as a percentage of gross value added and in constant value, but has increased in other reviewed countries (Table 1.4). Gross domestic expenditure on R&D for agricultural and veterinary sciences in government and higher education organisations increased in constant value in all reviewed countries for which data are available.

Public funding mechanisms for agricultural research has also changed, as the share of competitive projects in total funding increases. Efforts to foster public-private collaboration have been made in most of the reviewed countries, using funding and institutional mechanisms. The importance of international co-operation is acknowledged in all the countries as it helps to reduce costs and to pool resources and exploit synergies on regional or global challenges.

Renewed policy attention is being given to improving the adoption of innovation in farms and firms through improvements in the enabling environment and specific investment support. Farm advisory systems are in transition to adapt to new needs and to provide a wider range of advice requiring re-training and flexibility. New intermediary actors have emerged to meet these needs.

Based on the experience in the countries reviewed, the common principles noted below would make the AIS more efficient and responsive to needs.

Table 1.4. Trends in public research expenditure

Level in 2017*, and change between 2000 and 2017

	GBARD[1]	Public GERD on agricultural science[2]	Agriculture BERD[3,4]	Food and beverages BERD[3,5]
Research intensity in 2017*				
<0.1%			Estonia, Latvia, Japan, Turkey	
0.1% - 0.5%	Turkey	Turkey	Canada, Korea	Latvia, Turkey, Switzerland
0.5% - 1.0%	China, Colombia, Netherlands, Sweden	Argentina	Australia	Canada, Estonia,
1.0% - 1.5%	Argentina, Australia, Estonia, Latvia, United States	Estonia	Netherlands	Sweden
1.5% - 2.0%	Brazil, Canada, Japan	Latvia		Japan
2.0% - 2.5%				
2.5% - 3.5%	Korea, Switzerland	Australia, Korea		Korea, Netherland, United States
>3.5%		Japan, Netherlands, Sweden		
Research intensity change between 2000 and 2017*				
Increase	Australia, China, Estonia, Japan, Korea, Sweden	Estonia, Korea, Latvia, Turkey	Australia, Estonia, Korea, Netherlands, Turkey	Estonia, Korea, Netherlands, United States
Stable	Brazil, Colombia	Japan		
Decrease	Argentina, Canada, Netherlands, United States	Argentina, Australia	Canada, Japan	Canada, Japan, Sweden, Switzerland
Research expenditure change between 2000 and 2017* (in 2010 Dollars; Constant prices and PPPs)				
Increase	Australia, China, Colombia, Estonia, Japan, Korea, Sweden, Switzerland	Argentina, Australia, Estonia, Japan, Korea, Latvia, Netherlands, Sweden, Switzerland, Turkey	Australia, Canada, China, Estonia, Japan, Korea, Netherlands	China, Estonia, Korea, Latvia, Netherlands, Turkey
Decrease	Canada, Netherlands, United States			

Note: * or nearest available year.

1. Government budget allocation for R&D (GBARD) is a funder-based approach for reporting R&D, which involves identifying all the budget items that may support R&D activities and measuring or estimating their R&D content. It enables linking these budget lines to policy considerations through classification by socioeconomic objectives. However, it provides only a partial indicator of investment in public agricultural research, since it refers to research funding instruments dedicated specifically to agriculture.

2. Gross domestic expenditure on R&D for agricultural and veterinary sciences (GERD), by government and higher education organisations. Data are not available for Brazil, Canada, China, Colombia, and the United States.

3. Business Expenditure on R&D (BERD) is the measure of intramural R&D expenditures within the business enterprise sector (regardless the sources of R&D funds).

4. BERD agriculture data are not available for Brazil, China, Colombia, Sweden, Switzerland, and the United States.

5. BERD food and beverages data are not available for Australia, Brazil, China, and Colombia.

Source: OECD (2017a), "Research and Development", OECD Statistics (database), https://stats.oecd.org/; and for Brazil, China and Colombia: ASTI (2017), Agricultural Science and Technology Indicators (database), www.asti.cgiar.org/data (accessed March 2018).

Improve the governance of agricultural innovation systems

Government priorities for agricultural research and innovation need to be co-ordinated and communicated clearly. They should be part of a longer-term strategy for agricultural innovation, which takes into account long-term challenges such as climate change, and consumer and societal demands. They should also be integrated into wider growth policy

strategies. A common finding from the country reviews is the need to better involve stakeholders in the definition of objectives, starting at an early stage of the definition process. For example in Canada, an objective of Value Chain Round Tables (VCRTs), which bring together key industry leaders from across the value chain with federal and provincial government policy makers, is to share information about challenges and opportunities, identify research, policy, regulatory and technical requirements, and to create co-operative long-term strategies.

Co-ordination between the various public and private research organisations at the national and sub-national levels needs to be improved. A good practice is to give a co-ordinating role to a specific national institution and to clarify the mandates of organisations. In Sweden, efforts to strengthen the general innovation system have focused on improving governance and linkages, including the grouping of public research institutes into a single holding entity. Financial and institutional mechanisms – such as consortia, networks, co-operative research agreements, funding of collaborative R&D partnerships and platforms for discussion and sharing information – help to improve co-ordination and knowledge on the respective activities of diverse actors.[7]

Research and innovation investments and outcomes need to be monitored and policy impacts evaluated against objectives. This should enable continuous improvement, but also help identify where more profound changes are needed to meet objectives. Comprehensive, coherent and regular evaluation procedures should be developed. Ideally, these should include independent evaluations and cover a wide range of indicators of efforts, outputs and impacts that go beyond research excellence and financial considerations. In Australia and the United States, research evaluation procedures are in place that include impact assessment.

Simplify research programming to improve effectiveness and transparency

In some of the countries reviewed, government funding of research and innovation goes through multiple channels, making access of funds and evaluation of programmes quite complex. Simplified programming of public R&D and innovation funding, and provision of clear information, preferably on a single platform, as done in the Netherlands, should improve access. The efficiency of research funding mechanisms should also be reviewed on a regular basis to ensure higher impact.

At the same time, a challenge is to explore innovative ways to generate new (breaking through) ideas to overcome current constraints, for example through demand-driven funding mechanisms.

Improve complementarity of public funding of agricultural R&D with private investment by focusing on areas with characteristics of public goods

Improving the complementarity between public research funding at the national, sub-national and international levels with private efforts would help better leverage public money. However, linkages between public and private research are not well understood. Estimating the impact of public expenditure on agricultural research on private research as part of evaluation procedures should help target public policy and improve complementarity. The United States offers a good example of complementarity between public and private agricultural research, facilitated by the strong investment of some multinational companies in agricultural research, and regular assessment of public research investments.

Knowledge infrastructure is a public good that facilitates public and private research activities and enables innovation. It is particularly important to support the development of ICT infrastructure and general purpose technologies, as well as specific knowledge infrastructure such as databases and institutions, which require long-term stable funding as done in Brazil. Since they joined the European Union in 2004, Estonia and Latvia have upgraded research infrastructure using EU structural funds. In some countries, however, the decline in public funding for agricultural research and the high reliance on project funding were identified as potential issues for the long-term performance of the AIS.

Governments should dedicate public funds to long-term riskier large-scope research projects and projects that aim to improve long-term sustainability in food and agriculture. They should also dedicate specific funds for policy-relevant research, i.e. research that generates information needed to improve policies.

Government should facilitate Public-Private Partnerships (PPPs) for research and innovation, when they bring additional benefits by providing guidelines, governance, and enabling R&D funding mechanisms (Moreddu, 2016). A first step is to remove institutional constraints to public research organisations to engage in co-operation activities with the private sector. Many of the general innovation policies of the reviewed countries include funding mechanisms that support PPPs. For instance, Canada offers PPP support as part of its agricultural policy.

In the reviewed countries where agricultural research is organised by commodity sector, research is often focused on improving profitability. Public co-funding thus needs to ensure broader sustainability issues are covered. An option is to create cross-sector thematic areas and projects, including environmental issues, or to broaden the scope and membership of existing commodity research systems. For example, some Research and Development Corporations (RDCs) in Australia address broader challenges at the supply-chain level.

Strengthen private contribution to R&D and innovation for food and agriculture

Agri-food industries are important actors in the innovation process. With the exception of Korea, the Netherlands and the United States, where business expenditure on food R&D as a percentage of gross value added is over 2.5% (Table 1.4), national processing companies in most of the reviewed countries have limited capacity to engage in research. Strengthening the capacity of smaller domestic companies to engage in research and innovation, possibly using incentives targeted to their needs, is important for the performance of the whole sector.

Business investments in R&D for food and agriculture have increased in constant value terms in all countries for which data are available since the 2000s (Table 1.4). Investments are normally driven by market demand, but governments also provide different kinds of incentives. They include direct investment support, tax incentives, and Intellectual Property Right (IPR) protection. Few mechanisms supporting innovation in private companies are sector-specific, but some programmes target innovation in small- and medium-size enterprises (SMEs) (e.g. the Small Business Innovation Research (SBIR) programmes in the Netherlands and the United States). The extent to which they benefit agri-food companies in the countries reviewed is not clear. The evaluation of programmes that support research and innovation in private companies should be strengthened to ensure they are efficient and reach their intended beneficiaries.

The increase in IPR protection in recent decades has prompted higher investment in food and agriculture research and innovation by enabling firms to recover their investment. In some of the reviewed countries, however, enforcement of IPR protection needs to be improved. The challenge for IPR regulations is to provide incentives for private investment in innovation without compromising the sharing of knowledge and further use for research purposes (OECD, 2013). To facilitate the innovation process, Australia grants innovation patents with a shorter protection of eight years. The Plant Breeders' Right, as provided by the International Union for the Protection of New Varieties of Plants (UPOV), offers commercial protection to the "breeder" of a plant variety, without compromising further breeding research and re-use from farmers' planting.

Governments should facilitate the development of alternative sources of funding for research and innovation, through appropriate legislation. They include farmers' contributions from levies; revenues from royalties or Intellectual Property, venture capital and Foreign Direct Investment (FDI). In Australia, Canada, Colombia, Sweden, and the United States, producer levies can fund agricultural R&D. This funding remains within the value chain, except in Sweden. The most comprehensive system is the Australian Rural Research and Development Corporation (RDC) model of co-financing of rural R&D activities and places interactions between public R&D and agricultural industries at the heart of the rural innovation system. In the Netherlands, revenues from patents fund research (Innovation Box).

Strengthen linkages within the agricultural innovation system and across sectors

Research and innovation in food and agriculture increasingly benefit from advances in other sectors and general-purpose research, such as genetics and digital technologies. It is thus crucial to promote and enable research co-operation across sectors. The integration of the agricultural system in the general innovation system should ensure better use of public funds, increased efficiency of innovation systems through the pooling of complementary expertise and resources, and higher spill-over across sectors. As they focus on local needs, regional innovation systems are well-placed to identify synergies across sectors and actors that can benefit rural development.

Stronger linkages between AIS actors (researchers, educators, extension services, farmers, industry, NGOs, consumers and others) also contribute to improving the efficiency and relevance of the system. This does not necessarily require institutional reforms, but rather mechanisms to facilitate connections and co-ordination. To foster balanced partnerships, governments need to strengthen and harness the capacity of private companies and farmer organisations to participate in research partnerships via project funding and support to networking and training activities, as done by the EU innovation and agricultural policy or the Canadian Value Chain Round Tables. The link between research and technical assistance, in particular, requires strengthening in many of the countries reviewed. This can be done by adding a technology transfer component to research projects, or by valuing and encouraging networking between researchers, advisors and producers.

It is important to facilitate the sharing of knowledge in order to strengthen innovation by improving public understanding of the importance of innovation in food and agriculture, in the sector and in society, and building trust in science through increased transparency and education. For example, Japan established a platform for open innovation in agriculture that includes all agricultural innovation actors, private companies, universities, and research institutions in non-agricultural sectors.

Facilitate international R&D co-operation

The countries reviewed recognise the benefits of international co-operation for national systems from national specialisation, international spill-overs, and improved capacity to respond to global challenges. There are many opportunities for public research to engage in bilateral, regional and multilateral co-operation in R&D and technology transfer that need to be explored. To facilitate international co-operation, governments can, for example, remove institutional constraints to public research organisations that impede the hiring of foreign researchers or trainees, or to engage in activities that are not directly of national interest. Governments can also support the integration of research data and sharing of experience at the international level, student and staff exchanges, and the sharing of equipment and laboratories. For example, Embrapa in Brazil created Labex (Virtual Laboratories Programme) to promote opportunities for institutional co-operation in agricultural research and to monitor scientific advances, trends, and activities of interest to agribusiness in partner countries. EU Member States illustrate the benefits from the EU-wide innovation policy, which supports collaborative, multi-country projects and provides complementary funding to national research and innovation organisations.

Strengthen farm advisory systems to facilitate adoption

The potential benefits of innovations are only realised if they are effectively implemented. Farm advisory systems need to be flexible in order to respond to changing demands at the farm level. A role for the government is to encourage a varied supply of relevant advice from diverse public and private suppliers, while ensuring needs are met. In the Netherlands, for example, a diversity of private companies provide a wide range of advisory services since the privatisation of the public service. In Estonia, the government provides guidance but delivery is made by independent organisations.

In such a pluralistic and competitive system, public resources should focus on services that the private sector typically under-provides, including advice to small, semi-subsistence farmers to broaden their opportunities, targeted advice on sustainable technologies and practices, and use experience to better understand issues and needs. In the United States, for example, support to technical assistance and research projects is provided for within agri-environmental policies. A role for the government is also to facilitate the sharing of experiences through networking, and the development of open databases, and to ensure advisors have up-to date knowledge – possibly through certification – and to facilitate continuous life-long training.

Address skills need in food and agriculture

Matching labour and skills demand from food and agriculture is a growing issue in many countries. Agriculture-related education in particular can contribute by becoming more attractive to students, anticipating new skills demand and adapting courses accordingly, offering long-life training to all workers in the sector. Governments should ensure training and re-training programmes respond to needs, including for digital, environmental and management skills, and cover all workers, including immigrants, women and seasonal workers. This requires discussion with education actors and the private sector to identify long-term needs. In the Netherlands, the Green Table was created in 2014 to continue collaboration among educational institutions on common interest regarding discussion and negotiation with the government; relationships between education and the labour market; and maintenance of a good knowledge infrastructure. The Netherlands also succeeded in making agriculture-related education more attractive and responsive to changing skills

needs in the labour market, and students' choices, by emphasising job opportunities and societal values. To meet future needs, it is important to change traditional public perception and to be more proactive in reaching non-traditional agricultural students.

Ensuring a stable and enabling policy and regulatory environment to facilitate investment

A broader role for the government is to ensure that the general policy and regulatory environment is conducive to investment that leads to productivity and sustainability improvements. Two areas for improvement are outlined in this section: regulations and sustainability incentives.

Modernise regulations

The regulatory environment for entrepreneurship affects food and agricultural companies. Following OECD Good Regulatory Practices (OECD, 2012a), the countries reviewed are encouraged to simplify their regulatory system where necessary, and to make regulations clearer, more transparent, more easily accessible, and more coherent across jurisdictions. Regulatory collaboration between and within countries should also be enhanced to reduce regulatory heterogeneity. For food and agriculture in particular, regulations should become more flexible and responsive to industry and consumer needs, and anticipatory of science and technology developments and changes in public perception. Modernisation of regulations in Canada involves rationalising the government's role, adopting incorporation by reference to update regulations, increasing the use of outcome-based regulations, increasing regulatory alignment with the United States (as part of regulatory co-operation), and reducing unnecessary administrative burdens. Regulatory co-operation between the United States and Canada provides an opportunity to revisit differences between federal and provincial regulations. While some regulations may be perceived as slowing innovation, others stimulate the development of innovative solutions that enable the industry to meet requirements. This is the case, in particular, with environmental regulation.

Align policies and regulations towards sustainability improvements

Regulations on natural resources are central to ensuring the long term sustainable use of natural resources. In large part, they determine access to and use of land, water and biodiversity resources, and impose limits on the impact of industrial and agricultural activities on natural resource (e.g. water pollution, soil degradation, greenhouse gas emissions). Several countries have set regulations to restrict agricultural land expansion to forested areas (e.g. Brazil and Colombia), to discourage farmland fragmentation (Turkey), or to prevent agricultural land conversion to urban uses (Japan and Korea). While qualitative comparison can be made based on country reviews, the evaluation of environmental regulatory stringency for agriculture and the role of regulations and their effectiveness require further investigation.

Evidence from the country reviews suggests that policy incentives towards environment and resource sustainability need to be realigned by removing environmental harmful subsidies, such as fuel tax rebates, and using taxation or market mechanisms to meet environmental objectives. Sweden was one of the first countries to introduce taxes on pesticides in 1984. Combined with other policy measures, the tax contributed to reducing pesticide sales by more than 50% nationally, and a large decrease in pesticide risks for human health and to the environment. The Netherlands introduced in 2013 a charge to fund the production of sustainable energy in addition to the standard tax on energy. Several

countries have undertaken promising initiatives to improve water management in agriculture, such as the introduction of water charges in Brazil, a new groundwater regulation in the US state of California, and the Canada-Ontario Lake Erie action plan to address phosphorus pollution.

There is also much scope to improve the governance and management of natural resources by strengthening environmental laws and regulations that define responsibilities and rights, and by identifying and tackling local conflicts. In particular, compliance could be improved by using modern technology and by providing to agencies in charge of monitoring compliance the necessary financial and skills capacity.

Using agricultural policy to strengthen the sector's long-term performance

In a policy and regulatory environment more conducive to sustainable and productive investments, agricultural policies can be used to address specific issues that are prone to market failures, while contributing to the long-term performance of the sector. A mix of approaches and instruments, including taxes, regulations or direct support, are available to address well-identified problems. For example, to increase public goods provision and to address negative environmental externalities, agricultural policies should directly encourage the reduction of pollution and promote the sustainable use of natural resources.

In this context, agricultural policies should focus more specifically on strengthening the drivers of productivity and sustainability, which are innovation, structural change, sustainable resource use, and climate change adaptation. For example, where markets fail, agricultural policy measures can be used to:

- Facilitate innovation directly by supporting investments in the modernisation and restructuring of farm and agri-food firms; the diversification of activities; the uptake of new technologies and digital-based opportunities such as the use of big data, precision farming and clean energy; collaborative activities and participation of farmers or farmers' representatives in knowledge networks. For example, agricultural policy in Canada includes programmes that target innovation directly. EU agricultural policy measures support farmers' participation in innovation networks and improvements in advisory services
- Facilitate structural adjustment using time-bound, non-distortive investment support, where needed, or "retirement package" payments as the voluntary restructuring scheme offered in 2006-08 to EU farmers and processors in the sugar industry to facilitate adjustment to the 2006 sugar policy reform.
- Strengthen incentives to sustainable use of natural resources and reduction of pollution. Governments can improve the design of agri-environmental programmes, using best available scientific and economic evidence basis to better target and tailor to actual needs. Increasing evidence supports the use of performance-based policies, which require an evaluation of policies and implementation of measurable performance indicators, as is done in Switzerland. Environmental impact assessment should apply to more agricultural activities. Sweden, for example, requires an environmental impact assessment for a wide range of agricultural activities, the cost of which is borne by farmers. Governments could also revisit the balance between regulation and economic incentives in view of fostering environmentally-friendly innovation; they could consider market-based approaches to further reduce environmental pressure and the development of environmental service markets, such as carbon offsets and water quality credit

markets. At the same time, efforts to provide targeted and tailored advice to farmers on sustainable and productive technologies and practices should be strengthened.

- Explore options for reducing GHG emissions from agriculture, in particular grazing livestock, facilitate farmers' adaptation to climate change, and initiate relevant research. For example, Australia has introduced an Emission Reduction Fund, which attributes funding to the most effective bidders to reduce GHG emissions.
- Support technical assistance to improve compliance as part of agricultural support programmes, as in US conservation programmes.

Farmers need effective risk management tools in order to innovate and adapt to climate change. The government's role should focus on preparedness, the availability of information systems, and catastrophic risks. Existing risk management policies, such as subsidised agricultural insurance schemes, should be reviewed and evaluated with regard to their long-term financial and actuarial soundness and in view of climate change risk. Business-as-usual risk management in the face of climate change means that more risk and responsibility is shifted to governments and taxpayers. Government action should move towards a more forward-looking resilience approach to enhance the capacity to absorb, adapt and transform in the face of external shocks. This includes funding R&D activities aimed at developing practices and technologies that enable farmers to manage risks more effectively (e.g. drought resistant seeds, water management technologies), and providing information on risk exposure and risk management methods to farmers, as done in Australia and the Netherlands.

Improving policy coherence

Develop comprehensive strategic plans, including the whole value chain

The whole policy package affects food and agriculture and it needs to provide consistent signals. An important step to improving policy coherence is to develop comprehensive strategic plans that ensure co-ordination between policy areas, clarify policy objectives and responsibilities across levels of government, and that take into consideration trade-offs among specific policy objectives and interactions between policy areas. Improving consultation and communication about policy action, transparency and accountability is also essential to building trust and increasing efficiency.

Comprehensive food and agricultural strategies should develop a vision to improving the long-term productivity and sustainability performance of the whole value-chain and its capacity to respond to future challenges and opportunities. For example, climate change adaptation and mitigation should be integrated as a cross-cutting aspect of agricultural and agri-environmental policies, as is done in the Netherlands and Sweden. Any plan should include clear operational objectives with measurable targets for evaluation. This requires flexible data and information systems for evaluation, and comprehensive evaluation procedures that ensure lessons learned are considered when developing new policies.

Policy strategies should cover the whole food chain. Productivity and sustainability do not only concern farms and farmers. The entire value chain is at play, and the policy framework needs to consider the performance of each segment, as well as the relationships between them. Retailers have a closer interface to consumers than farmers, and agro-food industries are the main buyers of farm products. Each stage of the value chain is implicated in lifting productivity and improving the sustainability of production. Indeed, in many countries the success in tapping into higher value opportunities for the farm sector hinges on

improvements along the food chain. The role of the government in improving the functioning of the value chain requires further attention.

Minimise policy incoherencies

Policy incoherence can slow or prevent progress towards improved productivity and sustainability in the sector. Policy incoherencies were observed among policy goals, across policy domains, within agriculture or innovation policies, or between policy approaches in all the countries reviewed. More work is needed, however, to identify inconsistencies, to require better measurement, and to develop strategies that build on synergies and are able to deal with trade-offs.

Different types of policy incoherence are reported in the reviewed countries. The following sequence of actions could help reduce incoherencies:

- Identify the main policy incoherencies, and address them, by separating and reducing the signals misaligned with a productive and sustainable agriculture from other parts of policies.
- Ensure that no new incoherencies are introduced. In the case of innovation, agriculture or environmental policies, introduce a rapid *ex ante* assessment, with deeper analysis only if needed, ensure that policy evaluations focus on results rather than just the level of implementation, and incorporate the objective of assessing coherence in future agriculture policy evaluations. In the case of other policies, encourage lawmakers to open their views on the indirect effects of related policies on agriculture.
- Encourage synergistic policy plans, build policy bridges, and support win-win policy solutions. Cohesion starts in high-level policy plans, which should consider reaching out to non-agriculture objectives. In so far as possible, solutions that can contribute to both productivity and sustainability objectives should be developed and promoted.

Target interventions to the issue at stake

As a general principle, policy interventions are most effective and efficient if they target a specific problem at hand. Agricultural policies, in particular, often suffer from imprecise definitions on the scope of intervention. The best type of policy action will depend on the specificity of the issue (general, rural, or sectoral), and the targeted population (farmers, landowners, or rural dwellers). If the problem is not specific to the agricultural sector, it is more efficient to start using a general or regional policy. For example, wider income or growth objectives require a non-sectoral policy, such as a territorial, bottom-up approach to rural development. The general social security system in OECD countries can be adapted to provide an income safety net for farm households. The specific needs of small, semi-subsistence farmers require using a wider range of policy approaches than agricultural policy.

Fostering the relevance and impact of country reviews

Country reviews are conducted in collaboration with experts in governments. They draw on internationally comparable data and analysis in the OECD and other international organisations, as well national information and expertise. This collaboration is essential to ensuring their accuracy and relevance, and increasing their policy impact.

Impact can include policy changes following policy recommendations, as well as improvements in policy-relevant data and analysis to address the information gaps identified. For example, following the Canadian review (OECD, 2015d), Canada adopted the 1991 Act of the International Convention for the Protection of New Varieties of Plants (UPOV 91) in 2015 and launched a review of Agriculture and Agri-Food Canada public funding for agricultural innovation in 2018. An important recommendation in the review for the Netherlands was to define long-term objectives for R&D and innovation (OECD, 2015e). The Netherlands responded by developing a strategic knowledge and innovation agenda. Social issues are central to this agenda and are implemented through multi-year mission-driven innovation programmes. Together with stakeholders, concrete goals are defined for a wide range of policy instruments. At present, the agenda is still under preparation but nearing completion.

Experience with country reviews and analytical studies underpinning the framework should help strengthen the framework in the future. Moreover, discussion of policy issues identified in the reviews have continued at government and research levels in some countries, and evidence on drivers of productivity performance and the link between innovation and productivity is increasing. As discussed earlier, there is a need for improved evidence in many areas.

The framework used to collect information and analyse policies in reviewed countries was used flexibly in each country. It is important to retain this flexibility while ensuring that important issues are covered. Areas for improvement were nevertheless identified, notably on considerations of policy coherence and trade-offs; the need to better account for food systems, in particular on the consumer side; and to the need to include other aspects of the food and agriculture system such as the bioeconomy, fisheries, and circularity in the system.

A number of information gaps were identified. There is a limited understanding of the determinants of productivity growth and the nature of sustainability challenges in specific contexts. This requires better indicators of productivity and sustainability, including at the disaggregated level (particularly for sustainability indicators), as well as improving and diversifying the analytical tools and approaches. More forward-looking approaches are needed to deal with fundamental uncertainties to anticipate future challenges. In all areas, primary agriculture receives more attention than the food industry, both in the literature and in actual policies. Greater efforts should also be focussed on exploring the potential of digital technologies to create, improve and maintain information systems. The country reviews indicated the need to improve information systems not only to guide research and innovation policies, but also to facilitate knowledge sharing. The development of indicators and tools is required to evaluate the performance of the agricultural innovation systems and innovation policy on a regular basis, taking longer-term effects into account. Limited information is available on the extent to which cross-cutting policies affect food and agriculture. The country reviews have started to contribute to filling this gap, but the evidence remains limited, and it remains difficult to understand the interactions between a general policy, such as improved access to credit for SMEs, and agriculture-specific measures, such as farm investment support.

Notes

1 See for example the G20 Agriculture Ministers' Declaration 2017 — "Towards food and water security: Fostering sustainability, advancing innovation", 22 January 2017, Berlin (G20, 2017); the Interagency Report to the Mexican G20 Presidency (G20, 2012); and the joint declaration of Agriculture Ministers at the meeting of the Committee for Agriculture at ministerial level at OECD on 7-8 April 2016 (OECD, 2016a).

2 The most comprehensive productivity indicator is the Total Factor Productivity (TFP), which reflects the efficiency with which firms combine inputs to produce outputs.

3 In this report, sustainability refers to the preservation of natural capital, i.e. environmental sustainability. This encompasses managing agriculture's use of natural resources to ensure their long-term viability and reducing the negative environmental impacts of agriculture production which can damage the natural assets. Sustainable agriculture production systems also need to adapt to the projected impacts of climate change and to mitigate greenhouse gas (GHG) emissions.

4 As defined by the Oslo Manual (OECD/Eurostat, 2018), innovation is a broad concept. It is more than research and development (R&D) and encompasses both the creation and adoption of innovation, which can be "new to the firm, new to the market or new to the world".

5 Australia, Brazil, Canada, the People's Republic of China (hereafter "China"), Estonia, Japan, Korea, Latvia, the Netherlands, Sweden, Turkey and the United States.

6 Efforts to improve TFP measurement are taking place within the OECD Network on Agricultural Total Factor Productivity and the Environment. Following the 2014 Meeting of Agricultural Chief Scientists (MACS) in Australia, where the issue of performance measures for sustainable agricultural intensification was discussed, the MACS formed a working group to review the status and availability of TFP, and assess whether it, or some other measure or combination of measures, would be sufficient to assess progress towards sustainable agricultural intensification. The Working Group prepared a White Paper on Metrics of Sustainable Agricultural Productivity, presented at the 2016 G20 MACS in China (G20 MACS, 2016).

7 Fuglie and Toole (2014) contains a detailed analysis of this issue and estimations of the impact of public expenditure on agricultural research in the United States on private agricultural research.

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Chapter 2. Productivity and sustainability challenges for food and agriculture

This chapter outlines the main challenges and opportunities for food and agriculture in the reviewed countries, provides an overview of trends in the sector's productivity and sustainability performance across countries, and identifies main knowledge gaps for a full understanding of the situation.

Despite their differences, the food and agriculture sectors in reviewed countries face common opportunities and challenges, and countries can thus learn from each other's experience in many areas.

- The growth and diversification of global demand offers opportunities to traditional exporters of agro-food products, but also the development of markets for products with specific attributes, in which competition is primarily based on quality. Most reviews encourage countries to diversify into these higher value products.
- For OECD competitive agro-food exporters, the main challenges are to respond to increased competition on global commodity markets, in particular from faster growing emerging economies, while facing stricter environmental requirements from domestic regulations and markets, and growing uncertainties about market access.
- At the same time, the lack of competitiveness and capacity in food processing industries is an issue for at least some part of the sector in many countries, limiting the expansion of agriculture, innovation and export capacity in the food system.

All countries also need to improve productivity growth and sustainability to foster a competitive and viable sector, which is able to sustainably respond to changing demand, generate adequate income for farming families, and contribute to the rural economy, in particular in countries and regions where agri-food activities are significant.

- Continuous innovation in technologies, practices and organisation facilitate the development of a more productive and environmentally sustainable food and agriculture sector. Acceptance of innovation by consumers and society is thus crucial.
- Improving productivity further remains a challenge both in highly performing countries, where easy adjustments have already occurred, and in less performing ones, which require changes in incentives and disincentives. Structural change, including farm consolidation and diversification of activities, can help in that regard. Structural change is happening in all countries but is more or less pronounced depending on how long ago it started and how fast it occurred. However, small, and low-income farms, with often lower productivity, remain in most countries.
- Despite a wide diversity of situations, environmental pressures are increasingly decoupled from agriculture productivity. Sustainability issues affect most countries but differ in terms of nature and extent, both between and within countries. In some countries, water scarcity is the main problem, while in others it is pollution from nutrients. Progress has been observed at least in some dimensions of agriculture sustainability in all reviewed countries, even if environmental pressures remain high. Percentage change in agriculture’s negative impacts on the environment has at least not exceeded percentage change in productivity gains (thereby experiencing relative environment decoupling) in most countries, with some countries reducing these impacts while increasing productivity (absolute environment decoupling).
- Climate change will modify the natural conditions for agriculture and increase uncertainties everywhere. This will affect the range of adapted products, and thus productivity, and type and degree of stress, from water, heat but also pests and disease, so adaptation is crucial.

Main challenges and opportunities for food and agriculture

The countries reviewed display a wide diversity of size, geographical location, natural conditions, economic situation, and policy environment (Annex B). The structural, economic and environmental performance of their food and agriculture sectors reflects this diversity, which also illustrates the different pathways to improving productivity and sustainability.

Growing demand for more diverse types of food from wealthier consumers offers opportunities to compete on quality rather than only on low prices in traditional large markets as well as smaller niche markets. Market signals guide the industry in responding to changing and more diverse demand, while government's role is to ensure markets function well using regulatory and competition policy. At the same time, societal preferences impose new challenges. Both developments require improved traceability along the food chain.

Main structural, productivity, sustainability and climate change challenges facing the food and agricultural sector in reviewed countries are summarised in Table 2.1. They include natural handicaps for farming, remoteness, labour and skills shortage or low labour productivity depending on the country, insufficient scale of operations, persistence of productivity gaps across farms and firms, land and water resource scarcity, natural resource management, water pollution by nutrients, vulnerability to natural disasters, the need to curb greenhouse gas emissions. Climate change is expected to increase uncertainties, variability and constraints in many cases, but will also offer new growing opportunities in some countries.

Productivity and sustainability improvements are essential for the sector to meet these challenges and respond to opportunities. In most reviewed countries, food and agriculture productivity and sustainability performance has improved, although significant differences across and within countries is observed. Annex A contains the definition of concepts and indicators used in the report.

Table 2.1. Summary of main challenges for food and agriculture

	Structural challenge	Productivity challenge	Sustainability challenge	Climate change challenges and opportunities
Argentina	Investment in rural and transport infrastructure	Regional and product differences in productivity growth	Deforestation, increased use of inputs affecting water and air quality	Increasing frequency of extreme weather events, melting of glaciers
Australia	Increasing differences between small and large farms. Remoteness of some farms	Availability of new technology. Drought and water shortages constrain productivity growth	Water and soil constraints, Greenhouse Gas (GHG) emissions	More severe water constraints
Brazil	Dualistic structure	Large productivity gap between subsistence and commercial farms	Land management, GHG emissions	Not included in the review
Canada	Production quotas, weak food industry, and small domestic market	Mainly in the dairy sector	Land management affecting biodiversity, regional water quality issues from excess nutrients	Better growing conditions in some regions, increased frequency of extreme weather events (floods, droughts), potential increase in pest and disease
China	Small farms dominate. Income gap between rural and urban households	Water resource constraints, small farms	Water resources constraints, pollution of soils and water, and expansion of intensive livestock production	Rising temperatures, more frequent extreme weather events, spread of pests and disease
Colombia	Small, subsistence farms	Large differences by commodity sector. Low productivity in dairy farms due to small scale, high input prices, poor transport infrastructure and inefficient value chain	Land management affecting biodiversity, GHG emissions, and intensive use of inputs	Rising and more erratic precipitations causing soil degradation. Rising temperatures requiring moving production in higher altitudes (Coffee). Melting of glaciers and disappearance of moorland
Estonia	Dualistic structure	Productivity driven by a small number of larger farms, high growth rates reflecting catch up	Local water pollution by nutrients	Better growing conditions despite potential increase in pests and diseases, and rainfall variability
Japan	Increasing differences between small and large farms	Labour shortages and ageing	High nutrient surplus driven by intensive use of fertiliser, GHG emissions.	Increased frequency of extreme weather events (typhoons)
Korea	Small farms dominate. Income gap between rural and urban households	Productivity gap with manufacturing sector, small farms	High nutrient surplus. Expansion of intensive livestock production, increasing nutrient surplus and GHG emissions	More typhoons; more erratic monsoons; warming in the South
Latvia	Dualistic structure	Productivity driven by a small number of larger farms, high growth rates reflecting catch up	Local water pollution by nutrients	Better growing conditions, increase in pest and disease, and rainfall variability
Netherlands	High land prices	Sustain growth with higher constraints	Water pollution by nutrients, GHG emissions and biodiversity	Increased frequency of extreme weather events, Water management
Sweden	Areas with natural handicaps (northern latitudes)	Low and declining growth rate for some sectors	Eutrophication, biodiversity and GHG emissions	Better growing conditions, prolonged cultivation period, climate favourable to other crops
Switzerland	Areas with natural handicaps (mountains)	Low and declining growth rate	Nitrogen surplus does not meet country targets	--
Turkey	Large number of small farms	Productivity gap between small and larger farms	Water scarcity, water quality and soil erosion	Increased water stress and temperature increase affecting agriculture
United States	Labour shortage	Declining growth rate	Water scarcity, pollution and soil erosion particularly in certain regions	Higher frequency of extreme weather events, higher water constraints in some regions

Source: Country reviews.

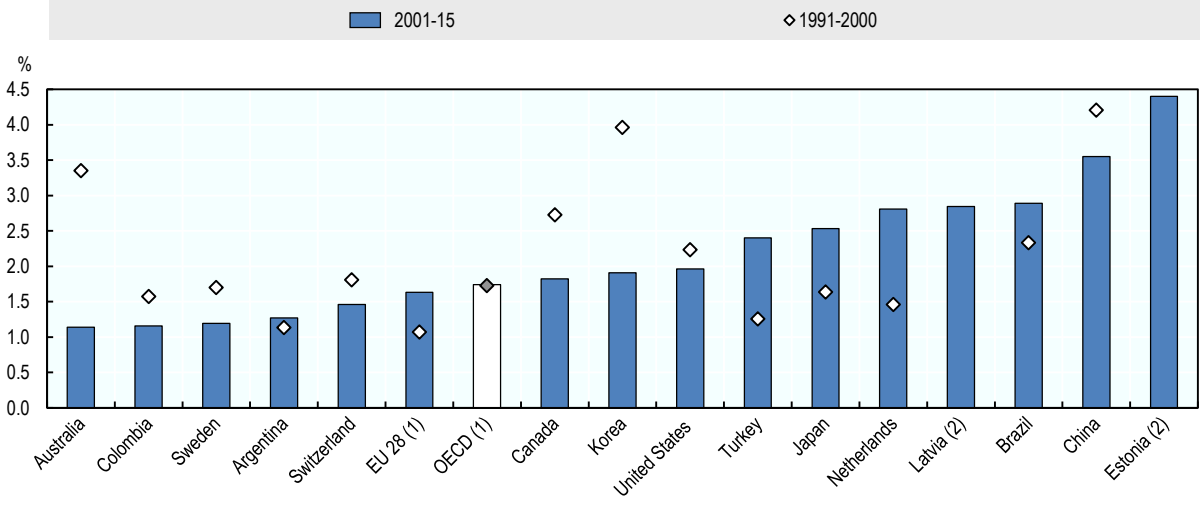
Trends in productivity growth

The most comprehensive productivity indicator is the Total Factor Productivity (TFP), which reflects the efficiency with which firms combine inputs to produce outputs (Annex A). According to USDA estimates, TFP has been the main source of agricultural production growth in recent decades. Since 2000, agricultural TFP growth has been strong — above 2% per year — in Estonia and Latvia (reflecting a catch-up following a decade of regression) as well as in the People's Republic of China (hereafter "China"), Brazil and the Netherlands, and to a lesser extent Japan and Turkey (Figure 2.1). In all these countries except China, annual TFP growth has increased since 2000, compared to the 1990s' annual average. In other reviewed countries including major agricultural producers and exporters, however, annual TFP growth is now lower than in the 1990s. This is particularly the case in Canada, Korea and the United States, although TFP continues to grow at an annual rate of close to 2%, and in Australia, where annual TFP growth is around 1.2% according to USDA estimates. TFP growth is also around 1.1% per year in Sweden,[1] Argentina, Switzerland and Colombia. Finally, TFP growth in Korea and especially Japan, which are net importers, is relatively strong.

In Canada and the United States, agricultural TFP growth over the long term mainly allows output growth without increasing input use, while in Estonia, Korea, the Netherlands and dairy farms in Australia, the decrease in input use, in particular labour, also contributes to TFP growth. In Australian broadacre farms, productivity growth over the long-term has been driven by reduced input use rather than output growth, while dairy productivity growth in the long term is mostly due to increased output rather than decreased inputs; but a structural shift post-2000 following deregulation (input use declining faster than output).

Figure 2.1. Total Factor Productivity in primary agriculture, 1991-2000 and 2001-15

Annual percentage growth



Notes: 1. EU28 and OECD averages. 2. 1991-2000 data are not available for Estonia and Latvia.
Source: USDA (2018), Economic Research Service, International Agricultural Productivity: www.ers.usda.gov/data-products/international-agricultural-productivity.aspx (accessed October 2018).

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Most reviews find that labour productivity growth, facilitated by farm consolidation and the adoption of labour-saving technologies, has been faster than TFP growth.

There are also large differences in productivity growth by farm type, size and regions as illustrated in some country reviews and recent OECD farm-level analysis. For example, over the period 2002-14, TFP growth in Sweden averaged 2.1% per year in pig farms, 1.7% in dairy farms and 1.3% in cattle farms, while TFP decreased by 0.9% per year in cereals, oilseeds and protein crop farms, reflecting faster growth in labour, capital and material inputs than output (OECD, 2018b). Moreover, regional differences in farm performance are a common feature of Swedish farms. In the case of rice in Korea, the 25% farms that have by far the highest market shares achieved a higher productivity growth at about 4% per year over the period 2003 to 2015, compared to 2% for the 50% average farms and 1.3% for the 25% smallest ones (OECD, 2018c). The productivity gap between the smallest 25% and the largest 25% of farms increased from 3.0 to 3.9 times between 2003 and 2015. The analysis indicates that the productivity growth of a small number of large-size farms is driving the TFP growth of the Korean rice sector. This is also the case of Estonian dairy farms (Kimura and Sauer, 2015). Recent OECD analyses also find that significant differences in farm-level productivity persist within countries, often linked to structural change dynamics (Box 3.1).

Productivity gaps thus remain significant among farms and production systems and improving the productivity of farms lagging behind remains a challenge even for the strong performing countries. Wider adoption of innovation and further economies of scale are required to bridge the gap between weaker and stronger performers, although several studies suggest focusing on the best-performing farm groups would be more efficient to improve overall productivity (e.g. Kimura and Sauer, 2015). Improving productivity growth more sustainably, while coping with new constraints and uncertainties from climate change, adds to the challenge.

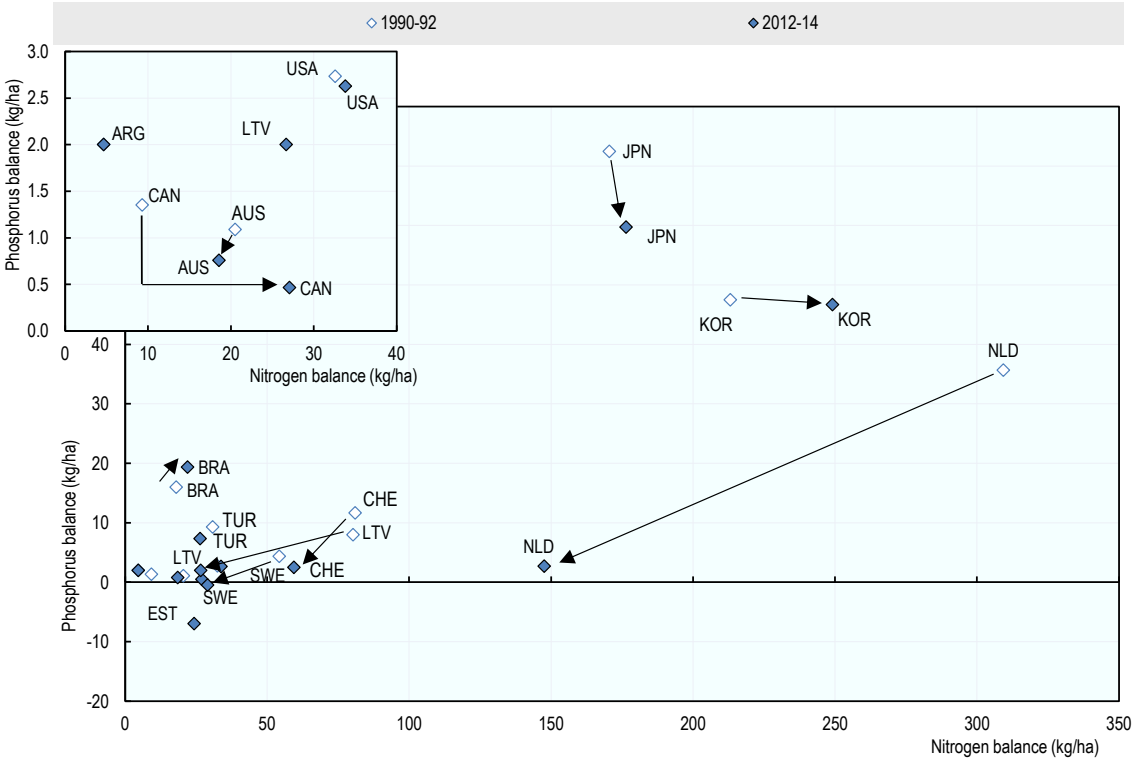
Trends in sustainability performance

Agri-environmental issues also vary in scope and severity in the reviewed countries, and the sustainability performance of agriculture differs by country and indicator. For instance, Figure 2.2 shows the performance of reviewed countries in terms of nutrient balances per hectare of utilised agricultural area. While an average decrease of per area nitrogen and phosphorous surpluses was observed between 1990-92 and 2012-14, not all countries face the same evolution, and the most recent figures do not all show a continued positive trend for all countries (Australia, Japan and Korea). Table A B.3 shows the evolution of reviewed countries in terms of resource management and selected environmental impacts.

If agricultural land use has been reduced, water and especially energy use have expanded in some of the reviewed countries (Table A B.3). Even in countries with overall abundant natural resources, like Argentina, Brazil or Canada, there is scope for improving the use of resources from agriculture and food activities, and challenges often remain at the local level. Turkey continues to face issues related to water variability and soil erosion. Within-country differences often exceed differences across countries. For instance, observed differences in water availability and use within Brazil, China and the United States exceed that across most reviewed countries, resulting in widely different resource constraints for agriculture. Even within small countries, like the Netherlands, the overall abundance of water resource does not exempt pockets of dry areas.

The environmental performance of agriculture is mixed among reviewed countries (Figure 2.2, Table A B.3). While progress in some indicators is observed in some countries, some are more advanced than others, and some countries have increased their environmental pressure. Countries with limited arable land, like Korea or the Netherlands, have more intensive agriculture systems resulting in relatively higher level of nutrient balance, water and air pollution, and pressure on water, soils or biodiversity (OECD, 2018d). Health and environmental risks from pesticides have decreased in Sweden. Fertiliser and pesticide use have increased significantly in parts of Brazil and Argentina. Chinese agriculture has developed rapidly without paying attention to its environmental impacts. China's use of agricultural inputs contributed to a rapid deterioration of agriculture-related ecosystems especially in certain regions. Agriculture has maintained or reduced total greenhouse gas (GHG) emissions in most reviewed countries, but the challenge remains significant especially for countries with strong animal production, like Australia, Brazil, Korea or the Netherlands for which agriculture accounts for a relatively larger share of total emissions compared to the OECD average.

Figure 2.2. Evolution of nutrient balances per area, 1990-92 and 2012-14



Note: The nutrient balances were estimated for Latvia; are not available for Estonia (1990-92), China and Colombia.
Source: OECD (2018a), OECD Agri-environmental Indicators (database), www.oecd.org/tad/sustainable-agriculture/agri-environmentalindicators.htm (accessed in April 2018).

StatLink https://doi.org/10.1787/888933998519

At the same time, for several environmental dimensions the agriculture sector's sustainability performance has been increasingly decoupled with agriculture productivity in many of the reviewed countries; that is, countries are increasingly able to sustain or even

improve agricultural productivity growth without commensurately increasing agriculture's impact on the environment (Table 2.2). However, such decoupling varies significantly by environmental and resource pressure and countries; in a few cases, countries' environmental deterioration has increased at a faster rate than agricultural productivity.

The sector also needs to prepare for changes associated with climate change, including higher levels of climatic uncertainties in most cases, but also increasing constraints on natural resource availability in some countries. Temperature increases are projected to reduce crop yields growth in already warm agro-climates, as in much of the United States (Schlenker and Roberts, 2009; Schauberger et al., 2017). Precipitation variability and the increased frequency of weather-related events is expected to have effects on most agriculture regions, imposing severe constraints on water availability in regions already subject to drought, such as in Turkey, Brazil or the United States. Northern countries, like Estonia, Sweden, and Canada, might increase their cropping season and benefit from better agro-climatic conditions on average, which may lead to the opportunity to adopt new crops. However, some of their regions may also face increased frequency and intensity of floods and the impacts from an expansion of pests and diseases.

Table 2.2. Decoupling agriculture productivity from resource and environmental pressure: Observed trends

Based on average annual change between 1998-2000 and 2010-12[1]

	Resource	Environment
Absolute decoupling[2]	Water use: Australia, Estonia, Korea, Netherlands Land use: Korea, Netherlands	Nitrogen and Phosphorous balance: Estonia, Sweden, Turkey, United States Ammonia: Netherlands, Sweden, United States Greenhouse gas (GHG) emissions: Netherlands, Turkey Pesticide sales: Netherlands, Korea, United States; Pesticide risk: Sweden
Relative decoupling[3]	Water use: China, Turkey, United States Energy use: Estonia, United States	GHG emissions: Estonia, United States
Deterioration	Energy use: Turkey	Pesticide sales: Turkey GHG emissions: Korea

Notes: 1. Time periods are not identical for each country, more recent date on agri-environmental indicators might alter this assessment. 2. Absolute decoupling refers to a situation in which resource impacts decline in absolute terms. 3. Relative decoupling refers to a decline in the ecological intensity per unit of economic output.
Source: Adapted from country reviews.

Main knowledge gaps

Despite on-going efforts to improve measurement of productivity and sustainability on a comparable basis across countries,[2] information on total factor productivity and sustainability performance is often limited both at the sectoral and farm level, and difficult to compare across countries. Moreover, uncertainties remain on the impact of climate change and more knowledge is needed on smaller-scale impacts or climate change as well as adaptation options.

International TFP comparison is hampered by data limitations. The only source of internationally comparable TFP growth estimates for agriculture is the USDA database, which produces TFP growth estimates for all countries on a comparable basis (USDA, 2018). However, some important inputs are crudely accounted for in these estimates, and efforts to improve estimations continue. Whenever possible, national and farm-level

estimates complemented international estimates in the reviews. In most cases, inputs and outputs considered in TFP calculations are those with a market value, but efforts are ongoing in OECD to develop environmentally adjusted TFP measures that include environmental effects of agricultural activities.[3]

The OECD agri-environmental indicators database contains valuable information, but not for all non-OECD reviewed countries and only at the national level. It would be useful to develop indicators at a more regional level to identify hot spots, in particular in large countries. Digital technologies could help the collection of disaggregated data at a lower cost.

While there is information on productivity and innovation in food processing firms in international databases,[4] most country reviews did not explore it fully. Moreover, it remains difficult to assess the economic and environmental performance of the food chain in general.

Notes

[1] EU estimates provide a slightly more optimistic picture of Swedish TFP growth of about 1.4% per year between 2005 and 2016.

[2] For example, agri-environmental indicators, agricultural total factor productivity, farm-level productivity and activities of the OECD Farm Level Analysis Network, and of the Agriculture Total Factor Productivity Network and the Environment.

[3] Cf. meeting of the OECD TFP and the environment network www.oecd.org/agriculture/topics/network-agricultural-productivity-and-environment/.

[4] See for example Day-Rubenstein and Fuglie (2011) (Chapter 9 in Fuglie et al., 2011) for information on research intensity in the food manufacturing industry, based on OECD data on Business Expenditure on R&D (BERD), and a comparison of productivity growth in the food manufacturing sector in the United States, the Eurozone, Japan and the United Kingdom, using the EU KLEMS database (www.euklems.net/index.html).

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Chapter 3. Drivers of agricultural productivity and sustainability performance

This chapter summarises recent empirical evidence from the country reviews and related work on drivers of farm performance and policy impacts on agriculture, which support the role of innovation, structural change and natural resource use and climate change in driving farm productivity and sustainability improvements. This review of available evidence also sheds light on a number of important knowledge gaps.

- The theoretical pathways between innovation and productivity are backed-up by empirical evidence from both sector-level and farm-level estimates.
- Adoption of innovation is the main driver of productivity growth and can improve sustainability if incentives to that effect are in place.
- Increasing evidence confirms the role of economies of scale in improving farm-level productivity, illustrated by the generally higher productivity performance of larger farms.
- The impact of structural adjustment on other performance aspects such as production, sustainability, animal welfare, and rural development is less obvious.
- The sustainable use of natural resources contributes to improving both productivity and sustainability performance.
- Improved sustainability performance of agriculture is partially driven by agriculture and economic development and societal demands.
- Climate change is expected to become a significant driver of productivity and sustainability performance; it generates agricultural risks and uncertainty and exacerbates the need for agriculture to mitigate previously unaccounted for environmental externalities.
- The drivers interact with each-other and are affected by other natural, market and policy factors.

The country reviews and recent OECD work on drivers of farm performance and policy impacts on agriculture contain empirical evidence supporting the role of innovation, structural change and natural resource use and climate change in driving farm productivity and sustainability improvements, and thus the relevance of the framework (Box 1.1). This review of available evidence also shed light on a number of important knowledge gaps.

In addition to policies, natural conditions, market incentives, and other considerations also affect these drivers, and thus productivity and sustainability achievements (OECD, 2015a). Innovation and adjustment in particular occur primarily in response to market-driven efforts to improve competitiveness, as long as policies do not impede them. Regarding natural resource use, however, markets often fail to provide signals reflecting societal demand, although some mechanisms exist (e.g. environmental labelling, emission trading mechanisms).

Innovation

Evidence gathered in country reviews confirms that innovation is a major driver of productivity growth and sustainability in many cases. Examples of productivity-enhancing innovations include: genetic improvement and the adoption of high quality seeds and animal breeds (most countries); the adoption of input-saving technologies and practices — such as no-till cropping (Argentina, Australia, Canada, the United States), milking robots (Box 2.3 in the Estonian review, OECD, 2018), modern buildings allowing energy savings and higher animal welfare, climate-smart greenhouses (Box 2.2 in the Dutch review, OECD, 2015b); technologies and practices for precision agriculture and better management of risks (irrigation systems, GPS assisted tractors, satellite images and drones); and changes in production management and marketing practices, including the

development of new products.[1] The role of organisational, product, and marketing innovations is particularly emphasised in the Netherlands (OECD, 2015b).

To complement country reviews and strengthen the framework, several OECD reports analysed farm-level productivity pathways, and confirmed the role of innovation in generating productivity gains. Analysing farm-level innovation in Dutch dairy and arable farms, Sauer (2017) finds that innovations related to improving processes, farm organisation and marketing resulted in significant productivity gains. Estimations identify a number of farm-specific characteristics, which affect the size and success of innovations. These are own product- and process-related development activities, farm size, the age of the farm operator as well as confidence in business and sector developments. Moreover, regulations and standards can create a demand-pull for innovation; and the level of co-operation with knowledge producing institutions improves the likelihood of success.

In analysing developments in dairy farm Total Factor Productivity (TFP) in Estonia, the Netherlands and the United Kingdom, Kimura and Sauer (2015) identify several pathways to improving productivity, including technological adoption and extension, efficient management of inputs and structural change (Box 3.1). Initial results of an analysis of drivers of farm performance in EU country cases also provide evidence of a positive correlation between innovation and productivity at farm level in crop farming in Hungary, dairy farming in the Czech Republic and Denmark, pig farming in Denmark, and fruit production in Chile (OECD, 2019a).

Structural change

Recent farm-level analyses, conducted at the OECD and in reviewed countries, confirm that larger farms are more productive than smaller ones. Indeed, they can better manage labour, and use scale-dependent technologies. These include larger combines and harvesters that allow cultivating more land with the same amount of labour, but also GPS-equipped precision agriculture technologies that allow reducing the amount of input use.[2] Operators of larger farms also have better access to knowledge, because of higher human and financial capacity. Similarly, larger agri-food firms generally have more capacity to carry out innovation activities, acquire technology, deal with regulations, and access export markets.

Scale economies are, however, context-dependent: the extent and magnitude of scale economies depends on relative factor prices; in agriculture, on topography and on infrastructure (for example, quality roads to move large volumes of inputs and products). Scale economies are also limited: there are few natural oligopolies in agriculture, and most large-scale farms can be still fairly small businesses.

The analysis of dairy farm productivity dynamics in four EU Member States illustrates the link between productivity growth and structural change (Box 3.1). An analysis of TFP trends for crop farms of selected EU Member States also shows that larger farms tend to be more productive than smaller farms (Bokusheva and Čechura, 2017). They appear to be in a better position to exploit economies of scale, although technical change may also have played a role. The analysis also found that there remains scope for improving economies of scales, and thus productivity among crop farms studied. Recent work on drivers of farm productivity also suggests that groups with larger farms tend to have higher productivity (OECD, 2019a), but more evidence is needed to better understand the relationship, which is probably not linear.

In the United States, pig industry developments illustrate the positive relationship between farm size and productivity performance, and the contribution of economies of scale to productivity improvement (OECD, 2016a). However, an ABARES analysis of Australian broadacre farms over the period 1977/78 to 2006/07 finds that while larger farms exhibit higher productivity than smaller ones, this is more likely due to differences in production technology than returns to scale (Sheng et al., 2014). Comparing productivity estimates in developed and developing countries, Rada and Fuglie (2018) suggest that the relationships between size and productivity may depend on context, and in particular development level.[3]

ABARES work reported in Box 1.1 in OECD (2015c) identifies resource reallocation, i.e. moving between farms of differing levels of productivity, as a significant driver of TFP growth in the broadacre industry, including when on-farm productivity growth was slower. Similarly, in a recent analysis of US grain-producing farms in the Corn Belt region discussing the contribution of structural change to productivity growth, Key (2018) estimates that the shift in production to larger, more productive farms explains one-sixth of aggregate productivity growth between 1982 and 2012, the reminder being attributed to average TFP growth in each farm-size category. Developments in the US pig industry also illustrate the connection between structural change and productivity growth, with the share of production in the larger, more productive farms increasing rapidly in the 1990s (OECD, 2016a).

Evidence on sustainability performance by farm size is more difficult to obtain and may be context-dependent. Initial results of the analysis of drivers of farm productivity mentioned above finds mixed evidence on the structural characteristics of more sustainable farms (OECD, 2919a). Countries with predominantly small farms often exhibit high nutrient surplus and emissions per ha (for example the Netherlands and Korea) due to intensive land practices. In the People's Republic of China (hereafter "China"), the extremely limited size of many farms results in many farmers spending most of their time in off-farm labour. As a result, these farmers use a significant amount of — often subsidised — agricultural inputs to compensate for their limited labour time. In contrast, farmers operating on large land properties in countries like Australia, Brazil, Canada or the United States often prefer to rationalise and limit their use of inputs to what they consider the minimum necessary to limit the total variable cost they incur.

Yet, farm size may not be as important for sustainability as for productivity. For instance, in their international meta-analysis, Balmford et al. (2018) find that production systems occupying less land per unit of product (higher yields) tend to generate a lower level of negative environmental externalities per unit production (greenhouse gas-GHG, water use, nitrogen, phosphorus, and soil losses) than others, although data remains limited. Blandford and Hassapoyannes (2018) also find that per ha GHG emissions are much larger in countries with extensive livestock system than in more intensive ones.

Box 3.1. Dynamics of dairy farm productivity growth in Estonia, Germany, the Netherlands and the United Kingdom

Recent OECD farm-level analysis found that improvement in labour productivity is the largest contributor to dairy sector-level productivity growth across countries. Structural change, characterised by a decline in the number of dairy farms and an increase in the average herd size per farm, led to lower labour input use associated with higher capital inputs, notably machinery and equipment.

Total Factor Productivity (TFP) growth before the phasing out of milk quotas is almost entirely driven by a decline in input use. However, the main driving force of TFP growth in the Dutch dairy farm sector became the expansion of milk output after the phasing out of milk quotas started.

Significant differences continue to exist in farm-level productivity within countries. In Germany, regional differences in average farm-level productivity persist. In Estonia, the evolution of sector-level productivity is largely driven by improvements in a small number of large farms, and the productivity difference between large and small farms increased overtime.

In the Netherlands and the United Kingdom, there has been a significant herd size expansion in all size classes of dairy farms and larger farms on average continue to achieve higher levels of productivity. However differences in productivity across farms have decreased over time due to the diffusion of technology across farms as well as the exit of less productive farms.

The analysis also shows that productive farms tend to be more intensive in some input use, such as higher stocking density, and use more purchased feed per cow. The direction of the impact of support payments on farm-level productivity is unclear as a whole, but the farms that obtain higher levels of non-farm income tend to have a lower productivity in the Netherlands and the United Kingdom. Those part-time farms may reduce the input intensity and may under-invest in productivity improving technology.

Source: Kimura, S. and J. Sauer (2015), "Dynamics of dairy farm productivity growth: Cross-country comparison", https://dx.doi.org/10.1787/5jrw8ffbzf7l-en.

The relationship between farm size and sustainability performance may also change above a threshold. In the US livestock sector, structural change and the closely connected set of innovations tied to it have led to major improvements in feed efficiency in hogs, dairy, and poultry, which by themselves reduce the amount of feed required per unit of meat or dairy production, and also reduce the amount of manure generated per unit of production. In turn, that reduces the environmental footprint of livestock agriculture (less land and chemicals needed for feed production). However, above a certain size, structural change has also led to the geographic consolidation of livestock and of manure, such that some locales now face excessive concentrations of manure (OECD, 2016a).

Natural resource use and climate change

Natural resource use and climate change clearly influence the range of possible products and choice of adapted production practices, and thus performance. In OECD countries, in the period 1998 to 2012, production growth has generally been achieved while reducing pressure on natural resources (land and water) but not always consistently reducing environmental impacts (Table 2.2).

In many instances, intense natural resource constraints, which posed a challenge for productivity growth, have been the trigger for technological, institutional and/or policy responses that have improved their situation (Gruère et al., 2018). For example, responses to intense droughts have been a major driver of a series of policy changes leading to the development of a sophisticated water allocation system in the Murray-Darling Basin in Australia, which will help farmers and others in the region to cope with future variability in precipitation (ibid.). In the United States, the 2014 drought, which forced farmers to use groundwater intensively, led to a ground-breaking regulatory response in California with the goal of securing groundwater reserves (Cooley et al., 2016). Similarly, the risk of flooding has encouraged the Netherlands to undertake a series of major policy initiatives under the Delta Programme, which included agriculture (OECD, 2016b).

On the contrary, endogenous constraints, such as insufficient, imperfect or asymmetric information, income constraints and costs, and misaligned policy incentives can deter further efforts by farmers to adopt climate-friendly practices. Wreford et al. (2017) showed that there is a wide diversity of barriers to the adoption of agriculture practices contributing to GHG mitigation or adaptation. They find in particular, that barriers relating to the actual or perceived effects of these practices on performance, as well as information and awareness involved in climate change decision-making and risk management, play a primary role in decisions regarding the adoption of climate-friendly measures. They also show that several of the identified barriers are created by existing agriculture policies (Chapter 4).

A cross-comparison of resource and environmental constraints, and the response undertaken by reviewed countries, highlights an evolution in policy priorities along three main sustainability challenges.

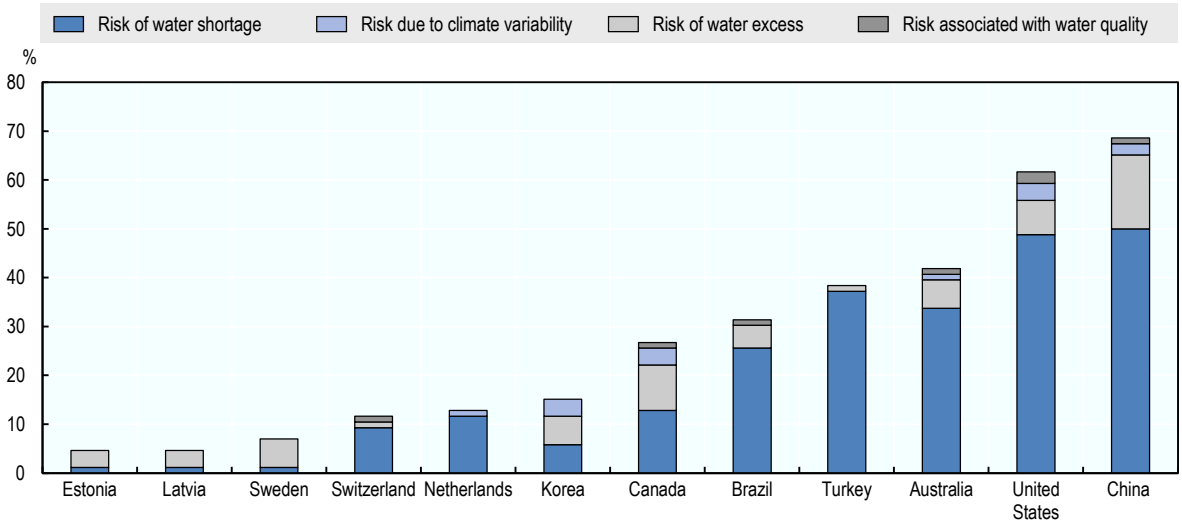
- The first major challenge is to use resources efficiently while continuing to develop agriculture. As the relative scarcity of natural resources increases, resource use cannot follow agriculture production growth, and therefore the sector is stimulated to innovate to improve agriculture productivity growth (producing more with fewer inputs).
- The second major challenge relates to observed negative environmental externalities from agriculture production, affecting mainly other users of natural resources and responding to societal demand for environmentally friendly agriculture practices. This includes in particular diffuse water pollution, which remains an issue in most reviewed countries. This phenomenon has encouraged governments to undertake policies to redress externalities and preserve the provision of agri-environmental public goods.
- The third and most recent challenge is associated with climate change. Governments' increased understanding of climate change consequences has induced a more emphatic focus on risk resilience in agriculture, and encouraged efforts to mitigate GHG emissions in agriculture, an environmental externality that was invisible and therefore not considered in the past. Reducing GHG emissions is a global challenge, which raises the possibility of "carbon leakage" (increased GHG emission in a foreign country when tackled domestically) and competitiveness. GHG emissions in agriculture have been included in the overall mitigation strategy of most OECD countries; but mandatory targets and policies that provide strong incentives to mitigate agricultural emissions have only been implemented in some OECD countries.

While all countries reviewed have engaged in responding to these three challenges, their degree of response and priorities vary depending on a number of factors, including countries' resource constraints, and their level of agriculture and economic development. For instance, while the Chinese government started to focus on water challenges in agriculture in the first decade of 2000, it only considered introducing agri-environmental policies in 2016, to accompany regulations to tackle environmental externalities. Brazil has made efforts to limit the impact of agriculture development on forests, stimulated in part by international agreements on climate change; however, it has not pursued efforts to reduce air or water pollution from agriculture with the same vigour. Turkey is currently focusing on means to increase water productivity as it continues to expand irrigation. In Australia, the main effort remains that of ensuring resilience of agriculture to water risks, but there are increasing societal demands to push towards sustainable development more generally. The Netherlands, facing land and environmental constraints to growth, has emphasised efforts towards higher productivity and lower environmental impacts. Korea and Japan have also increasingly engaged in efforts to lower the negative impacts of agriculture, while considering how to adapt to climate change. Estonia and Switzerland, not facing as strong resource and climatic constraints, have emphasised the environmental quality challenges, including mitigating GHG emissions, as a priority for their agriculture policies.

Still, more efforts are needed to tackle future climate and water risks in the reviewed countries. While amplitude of impact varies across scenarios, climate change projections suggest negative impact for agriculture in the reviewed countries. Ignaciuk and Mason-D'Croz (2014) find that the yields of maize, wheat and rice would decline by 10%, 7% and 6%, respectively on average in OECD countries, compared to a situation where the current climate conditions would prevail, in the absence of adaptation action. Yields could reduce by as much as 25% in the case of maize in North America or wheat in Australia. Furthermore, existing projections suggest that, unless a response is undertaken, future water risks will continue to affect all reviewed countries although their likelihood and type of risks vary significantly across countries (Figure 3.1). The agriculture productive regions of Northeast China and the Southwest United States could face particularly high water risks due to climatic water supply limitations and continued increased demand from non-agriculture water users (OECD, 2017a). Both climate and water risks were associated with expected commodity price increases at the time, affecting other actors in the market and potentially food security (Ignaciuk and Mason D'Croz, 2014; OECD, 2017).

Figure 3.1. Future water risks in reviewed countries in the absence of adaptation action

Frequency of global water risk assessments identifying a country as subject to high or very high future water risks without further action



Note: The figure indicates future water risks starting from current situation.
Source: OECD (2017), *Water Risk Hotspots for Agriculture*, https://dx.doi.org/10.1787/9789264279551-en, based on a review of 64 studies.

StatLink https://doi.org/10.1787/888933998538

Common drivers for agriculture productivity and sustainability

Quantitative analyses of sustainability and productivity are being developed, including using farm-level econometric estimations and modelling approaches. For instance, Lankoski et al. (2018) analysed policy coherence between climate change adaptation, mitigation and productivity, and applied their model in the case of Finland. Using farm level data, they simulated the projected impact of selected policies on TFP, climate change adaptation (modelled as reduced yield variability), GHG emissions, and nutrient balances, accounting for risks and risk behaviour. The analysis shows that policy choices generate inherent trade-offs between productivity, mitigation and adaptation (Chapter 7). An alternative approach combining qualitative and quantitative evidence is that of Fuzzy Set Qualitative Comparative Analysis. OECD (2019b) uses this method to investigate the possible impacts of specific agriculture policy and agriculture structure on productivity and environment.

Main knowledge gaps

Despite continued efforts, the measurement of TFP remains challenging, with different methods and data limitations. These difficulties increase when attempting to incorporate environmental performance in TFP, as information quality and availability remains a limitation.

The diversity of situation also makes generalisation difficult unless evidence from a significant number of diverse sources concur, as is the case for linking innovation and productivity. This suggests the need for increased and concerted efforts across institutions

and countries to improve understanding of the different pathways, and underlying conditions leading to improved performance. These are key to improving policy design.

Notes

[1] See examples of productivity-enhancing technologies in crop and dairy farming in the Estonian review (Box 2.3 and Box 2.4 in OECD, 2018). The US review (OECD, 2016a) reports that steady increases in corn yields resulted from a series of successive biological, mechanical, and chemical innovations resulting from public and private R&D, rather than from any single innovation, and that rapid diffusion of those innovations among farmers played a further important role in driving yield growth.

[2] See Key (2018) for a discussion of the role of technologies in reducing input costs.

[3] Rada and Fuglie (2018) report that larger farms have a higher TFP in Australia, Brazil and the United States. In Brazil, the relation between income size and TFP is not linear, but U-shaped, and smaller farms are more productive than medium-sized ones (based on income). Smaller farms are also more productive than medium-sized farms in the developing countries investigated in the article (Bengladesh, Malawi, Tanzania and Uganda).

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Chapter 4. Agricultural policy environment

This chapter outlines the diversity of agricultural policy measures and associated support to producers and to general services to the sector in reviewed countries. It discusses the extent to which the different measures affect the drivers of agricultural productivity and sustainability: innovation, structural change, natural resource use and climate change. Outlining the importance of general services to improve the long-term performance of food and agriculture, this chapter consolidates the recommendations for agricultural policies made in country reviews.

- Reviewed countries display a diversity of agricultural policies: levels of support to producers range from 1% to more than 50% of gross farm receipts, and the policy mix includes a variety of instruments, from price support and broad direct payments to more targeted measures.
- Most agricultural policy support goes to individual producers, although support to general services to the sector is best at enabling long-term performance in both food and agriculture.
- Agricultural policy heavily influences farmers' decisions in countries that rely on high support levels, and where the share of support that distorts the most production is highest within the overall policy mix. Such support, based on output or variable input use without constraints, negatively affects productivity and sustainability.
- Other countries rely more heavily on income support with limited distortions to markets. This may increase investment capacity to innovate, but also slow structural adjustment, and thus productivity growth.
- Most reviewed countries provide investment support to farmers, often as a means to facilitate adjustment and acquire modern equipment to increase productivity. In the presence of regulatory and policy incentives, this can also improve sustainability.
- Many reviewed countries make efforts to improve risk management tools for farmers, including a few which already rely heavily on specific risk management measures. More effective risk management can facilitate innovation, which is a risky business, but government support in this area may encourage unsustainable behaviour.
- Efforts to improve agriculture's environmental outcomes include regulations on resource use, the removal of negative policy incentives, and payments to change practices, taxes and education programmes. The design of payment programmes (practice versus performance based) may influence their environmental effectiveness.
- Climate change policies are still in development, with most countries having taken action on adaptation, much fewer on mitigation.
- In some countries, agricultural policy compensates for failures in other policy areas (such as credit, competition).

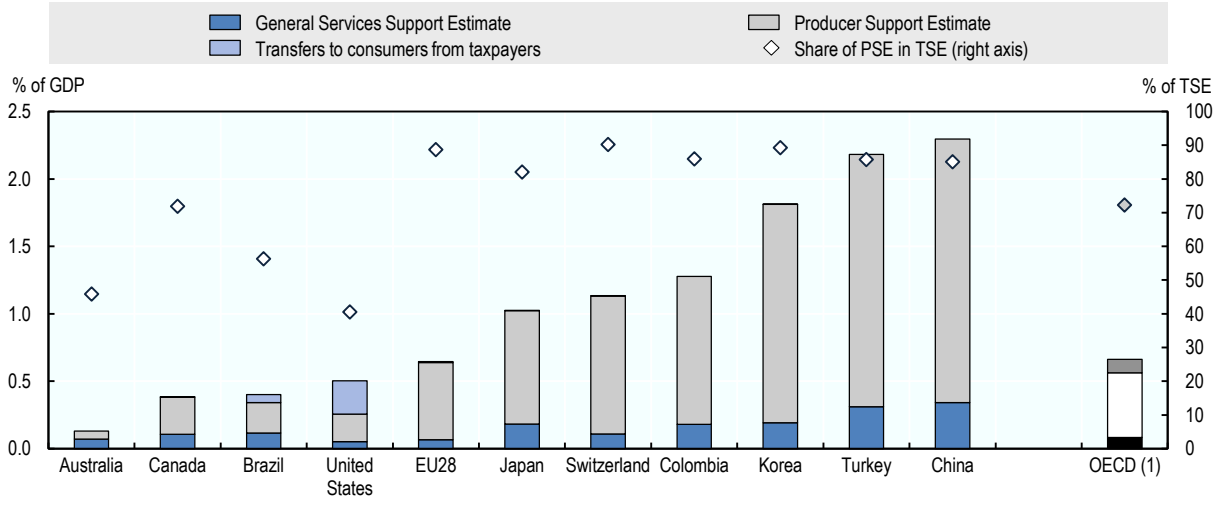
Agricultural policy affects farm investments and practices through a variety of instruments, with different intended and unintended impacts on structural change, natural resource use and innovation, and thus productivity and sustainability in food and agriculture.

Reviewed countries have very different agricultural policy environments in terms of support level and type of policy measures (except for members of the European Union that implement the Common Agricultural Policy). For example, some rely heavily on direct support to production or income, while others provide risk management tools or support general services to the sector as a whole.

Most support to agriculture goes to individual producers

Support to individual producers (measured by the Producer Support Estimate, PSE) accounts for over 80% of total support to the sector as a whole (measured by the Total support Estimate, TSE) in eleven out of fifteen countries (Figure 4.1).[1] Australia is an exception as support to general services to the sector (GSSE) accounts for over half of the TSE, but this share is also about 30% of the TSE in Brazil and Canada. In the United States, about half of the TSE is comprised of government expenditure to consumers from food programmes, with negligible links to agricultural productivity or sustainability. Of the remainder, around 80% is support to individual producers.

Figure 4.1. Composition of total support to agriculture, 2015-17



Note: 1. The OECD total does not include the non-OECD EU Member States.
Source: OECD (2018a), "Producer and Consumer Support Estimates", *OECD Agriculture statistics* (database), https://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink https://doi.org/10.1787/888933998557

As a result, agricultural producers derive a significant share of their income from government support in many countries. At one end of the spectrum, producer support accounts for close to or above 50% of gross farm receipts in Japan, Korea and Switzerland. At the other end, the share of producer support in gross farm receipts of Australian and Brazilian producers is below 3%. In comparison, the OECD average was 18% in 2015-17 (Figure 4.2).

Using information contained in the PSE database, Table 4.1 summarises the main characteristics of support to producers derived from agricultural policies.

Table 4.1. Summary of approaches to agricultural policy, 2015-17

Share of distorting support in gross farm receipts (%)	%PSE[1]	% share in PSE				% share in all direct payments of least distorting payments[3]	Annual average TFP growth 2001-14 (%)	Environmental Progress in Agriculture Index (EPAI) 2004-14[4]
		MPS[2]	Investment support	Direct payments	With input constraints			
< 1%								
Argentina[5]	..	-13.6	..	..	..	..	..	2.4	..
Australia	0.1	1.7	0	24	56	19	85	1.2	0.4
Brazil	0.9	2.7	29	28	3	69	0	2.9	..
1-10%								
United States	3.1	9.6	28	4.2	50	54	50	1.9	-0.1
European Union[6,7]	5.2	19.3	20	6	65	60	65	1.6	-0.4
Canada	6.5	9.3	63	1.7	28	0	0	1.9	0.3
OECD	9.4	18.2	46	4.1	40	36	59	1.9	-0.1
10-20%								
Colombia	11.3	13.1	82	4.6	0	10	..	1.1	..
China	11.8	15.5	73	7.3	15	1	20	3.3	..
> 20%								
Turkey	23.1	25.3	81	1.6	8	1	0	2.4	0.7
Switzerland	30.5	56.0	49	1.2	42	42	67	1.1	-0.1
Japan	39.4	46.0	81	1.3	12	6	55	2.5	-0.1
Korea	47.6	52.3	90	0.7	8	4	44	1.9	0.4

Notes: TFP: Tota1 Factor Productivity; ..: Not available.
1. Producer support estimate as a share of gross farm receipts. 2. Market price support. 3. Payments based on fixed parameters and based on non-commodity criteria as a share of all direct payments. 4. The EPAI measures the difference between the proportion of nine selected agri-environmental indicators (agriculture methane emissions, agriculture nitrous oxide emissions, agriculture ammonia emissions, direct on-farm energy consumption, total pesticides sales, agriculture freshwater abstraction, nitrogen balance, phosphorus balance and farmland birds index) that registered positive growth and those that registered a negative growth between 2004 and 2014. A positive value (from 0 to +1) indicates an increase in the number of environmental pressures while a negative value (from 0 to -1) indicates a decrease in the number of environmental pressures. 5. %PSE, 2015-17 from OECD (2019a). 6. Among reviewed EU countries, TFP growth ranges from 1.4% in Sweden to 3.8% in Estonia. 7. EU figures for EPAI include only the 22 OECD members.
Source: OECD (2018a), "Producer and Consumer Support Estimates", *OECD Agriculture statistics* (database), https://dx.doi.org/10.1787/agr-pcse-data-en; USDA (2018), Economic Research Service, International Agricultural Productivity: www.ers.usda.gov/data-products/international-agricultural-productivity.aspx (accessed October 2018).

Most support to producers is not linked to outcomes

Support levels give an indication of the reliance of producers on government intervention, but in terms of productivity and sustainability impact, the composition of support matters.

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 practices that do not take adequate consideration of longer term environmental sustainability.[2] For instance, fertiliser subsidies used in the People's Republic of China

(hereafter "China") have contributed to increasing crop production at the cost of the environment.

Moreover, being for the most part commodity specific, this type of support favours products that may not be the most adapted to the region, to a changing climate, and impedes adjustment towards more productive and sustainable production choices (Ignaciuk, 2015; Wreford et al., 2017).

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 the effects of decoupled income support payments on productivity may be small, particularly where farm credit is not constrained as observed in Sweden. Furthermore, 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.

Research on the impact of US decoupled payments on farmers' decisions suggest they had negligible effects on the adoption of innovations or farm productivity: recipients did not invest at a higher rate than non-recipients, and although payments have increased household wealth they have led to no or modest changes in farm operating decisions (OECD, 2016a).

The impact of decoupled payments on the environment will generally be limited, although the context and type of impact matters. Existing studies find that partial decoupling tends to have a neutral or negative impact on biodiversity as they tend to homogenise agriculture production and in some cases encourage land abandonment (OECD, 2019b). Ongoing OECD analysis suggests that the marginal environmental effect of an increase in direct payments decoupled from production on nitrogen balances and greenhouse gas emissions is negligible (Henderson and Lankoski, 2019). At the same time, absolute effects may depend on the context. Lankoski et al. (2018)'s crop farm level model simulations in Finland suggest that decoupled area payment may increase GHG emissions and nutrient runoff compared to no policy, in the case when decoupled area payment is paid for cultivated cropland but not for idled land. A similar simulation using US regional data finds that decoupled crop area payments have no impact on productivity or mitigation of GHG (Lankoski, Ignaciuk and Jésus, 2018). Further, decoupled payments may have a cushioning effect in some cases that could affect the risk behaviours of farmers.

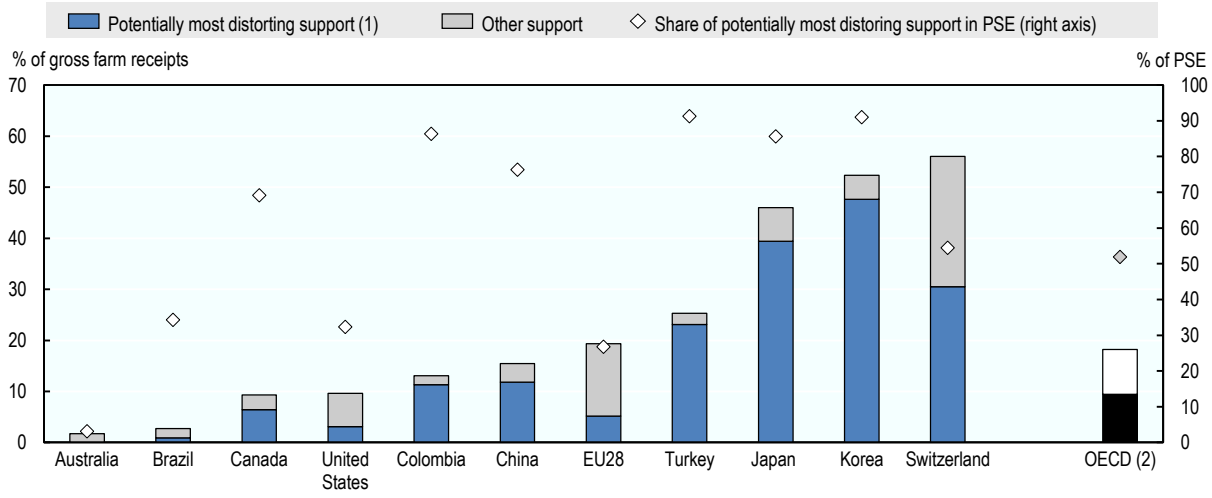
Investigating the determinants of Total Factor Productivity (TFP) growth in crop farms of selected EU Member States, Bokusheva and Čechura (2017) found that farm support payments negatively affect crop farm productivity and efficiency of input use. Farms receiving higher payments per ha or per tonne produced displayed lower TFP growth and higher persistent technical inefficiency, controlling for farms located in areas with natural handicaps. Payments more decoupled with production were found to affect productivity less than other forms of support.

In about half the countries considered, support is predominantly provided through measures that are considered most distorting to production and trade (Figure 4.2and Figure 4.3). This is support based on output (including market price support and output payments) and on the unconstrained use of variable inputs. These include high support countries like Japan and Korea, as well as countries with lower support levels, where these types of support, collectively termed "most distorting support", account for a relatively small share of gross farm receipts. For example, most distorting support accounts for three-quarters of producer

support in China, but only 11% of gross farm receipts in 2015-17. Similarly, EU support to producers accounted for 20% of gross farm receipts, but most distorting support only 5%. Conversely, countries with a lower share of most distorting support include countries with higher support levels. For example, the share of most distorting support is about 50% of producer support in Switzerland and 90% in Turkey, but their share in gross farm receipts is lower in Turkey (23%) than in Switzerland (30%).

In countries with a large share of "other support" such as the European Union, Switzerland and the United States, a large part is made of broad based direct payments with varying links to production parameters, and conditions attached to them. For example, two-thirds of direct payments in the European Union and over 40% of payments in the United States are not linked with current production parameters and do not require production, while over half of payments in Switzerland are not linked with current production parameters, but require production for the most part. In other countries, most payments are based on current area, animal numbers of income.

Figure 4.2. Composition of Producer Support Estimate, 2015-17



Notes: 1. Support based on output (including market price support and output payments) and on the unconstrained use of variable inputs.
2. The OECD total does not include the non-OECD EU Member States.
Source: OECD (2018a), "Producer and Consumer Support Estimates", *OECD Agriculture statistics* (database), https://dx.doi.org/10.1787/agr-pcse-data-en.

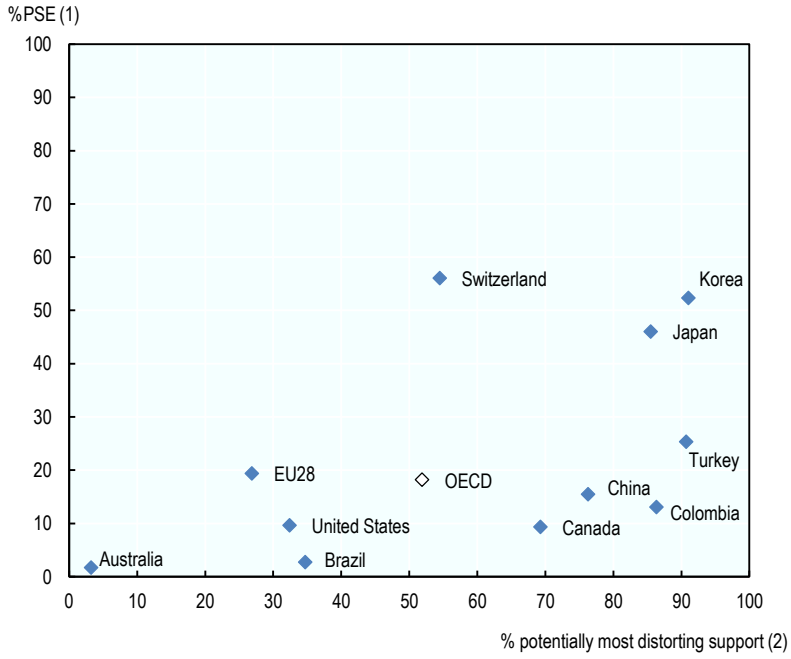
StatLink https://doi.org/10.1787/888933998576

Other types of support include investment support and payments for more specific purpose such as compensation of income losses or agri-environmental payments; these are discussed later.

In some countries, a high share of support is specific to single commodities. This includes market price support (MPS), output payments as well as payments based on area planted in specific commodities or animals. Rice and cotton are the commodities receiving highest levels of commodity-specific support, mainly in the form of price support for rice and sugar, and mainly using specific payments for cotton (Figure 1.11 in OECD, 2018b). However, differences in commodity-specific support, across commodities, have decreased across commodities in the last 15 years.

In countries with the lower levels of support and (relatively more) limited use of most-distorting forms of support, such as Australia and Brazil, exposure to competition has been particularly fundamental to incentivising innovation.

Figure 4.3. Producer Support Estimate level and composition, 2015-17



Notes: 1. Producer Support Estimate (PSE) as a share of the gross farm receipts.
2. Potentially most distorting support as a share of the PSE.
Source: OECD (2018a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), https://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink https://doi.org/10.1787/888933998595

Some measures target innovation, structural change, natural resources and climate change

While all policy measures affect drivers of productivity and sustainability, some measures target innovation, structural change, natural resources and climate change more directly. These include: agricultural investment support, which facilitates investment in new technologies, and is sometimes conditional on innovation or sustainability improvements; support for advisory services when delivering advice to individual producers (considered in the next section); various measures facilitating labour or land adjustment; and incentives for the adoption of more sustainable technologies and practices.

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 explicitly target the desired environmental outcome would steer farmers towards innovative sustainable practices more effectively than broad-based measures (OECD, 2015a).

Few of the reviewed countries provide direct support to innovation through agricultural policies. Examples are found in Canada, with the AgriInnovation programme of Growing Forward 2 (Box 4.1); and in the European Union where Pillar 2 of the Common Agricultural Policy (CAP) includes since 2015 a number of optional measures to facilitate participation in innovation networks and co-operative approaches to innovation (Box 4.2). However, in most reviewed countries investment support has facilitated the adoption of new technologies and practices leading to productivity and sometimes sustainability improvements. Investment support has also facilitated farm consolidation.

For a long time, most countries have provided investment support to farmers, in the form of grants or cheaper loans, to co-finance the acquisition of land, buildings or equipment, often based on approval of a development plan. This can be part of a setting-up of young farmers, the development of new activities, changes in practices or upgrade of technology. The effect of investment support has been particularly spectacular in transition economies like Estonia and Latvia, where governments chose to dedicate a larger than EU average share of Pillar 2 CAP payments to investment support, and where some investment support originally aimed at new Member States upgrading farm and food processing facilities to meet EU safety and sustainability requirements. Other countries like China and Turkey have made significant efforts to improve agricultural and rural infrastructure.

In the United States, farm investment has taken place without specific government support to farm investment, but in the current Farm Bill support to young farmers and ranchers was introduced to address a specific market failure. In Brazil, farm credit support is a major instrument of agricultural policy, with two different programmes for commercial farms and for smaller subsistence farms, mainly to compensate for failure in credit markets. In EU agricultural policy, investment support is also to compensate partly for high land prices, which make it particularly difficult for young farmers to set up. However, in most cases, farm investment support programmes have been long-established. While credit market failure may have been a justification when farm investment support was first introduced, conditions may have changed and so the rationale for farm investment support may no longer apply in some countries, called for regular assessment of needs. Further, it is difficult to evaluate the impact of such programmes because of difficulties in assessing the extent to which investment would not have occurred in the absence of investment support.

In many reviewed countries, food processing industries have not invested and consolidated as much as agriculture and lack capacity to innovate. In Canada and the European Union, however, some programmes are also available for co-operatives and the restructuring of first stage processing, in particular as part of reform packages (e.g. EU sugar reform). EU support is also available for diversification of activities, including for adding value through processing at the farm. This usually facilitates adjustment of labour and capital resources, the former being often under-employed in smaller farms.

Box 4.1. AgriInnovation in Canada

The AgriInnovation Program of Growing Forward 2 addresses the three stages of the innovation continuum: from research, to technology transfer, to the commercialisation and adoption of innovation. It contains three streams of innovation initiatives:

1. The Research Acceleration Innovation stream led by Agriculture and Agri-Food Canada (AAFC) addresses emerging science-based requirements of the sector through research development and knowledge transfer activities to identify and mitigate risks to production, keep pace with sustainability considerations, improve productivity and capture market opportunities. It targets far-from-adoption, cross-cutting research.
2. The Industry-led Research and Development stream supports pre-commercialisation research, development and knowledge transfer for innovative agriculture, agri-food and agri-based products and processes. This stream may provide financial support to approved applicants, and/or support in the form of collaborative assistance given by AAFC research scientists and experts for knowledge transfer. It provides support to two types of projects: Agri-Science Clusters and Agri-Science Projects.
    - Agri-Science Cluster support aims to mobilise and co-ordinate a critical mass of scientific expertise in industry, academia and government. Funding is available to not-for-profit and for-profit applicants (the latter under certain conditions); partners can include AAFC researchers/resources (under a Collaborative Research Agreement). It is national in scope, industry-led, and addresses components of the sector's applied science plan under a single application. Maximum funding, in the form of a non-repayable contribution, is CAD 20 million over five years and requires industry contribution.
    - Agri-Science Projects are less comprehensive, but available for a single research project or a small set of projects. Their scope may be national, regional or local, and for profit and not-for-profit organisations are eligible. Maximum funding, in the form of a non-repayable contribution agreement, is CAD 5 million and requires industry contribution.
3. The Industry-led Commercialisation and Adoption stream aims to facilitate the demonstration, commercialisation and adoption of innovative agri-based products, technologies, processes or services. This stream provides support to approved industry-led pre-commercial demonstration, commercial or adoption projects.

These federal initiatives are complemented by cost-shared programmes with provinces and territories, which are designed to reflect the innovation requirements unique to different provinces and territories to address the broader innovation objective of the country.

Source: OECD (2015b), *Innovation, Agricultural Productivity and Sustainability in Canada*, https://dx.doi.org/10.1787/9789264238541-en using www.agr.gc.ca/eng/?id=1354301302625.

Box 4.2. Choice of EU support in national Rural Development Plans 2014-20

In EU Member States, national or regional Rural Development Plans (RDP) funded by Pillar 2 of the EU Common Agricultural Policy (CAP) have for a long time included support for investment and the adoption of environmentally-friendly practices. For the period 2014-20, governments can also choose to support risk management tools, knowledge transfer (M01 and M02), collective actions, such as the setting-up producer groups and organisations (M09) and co-operation (M16).

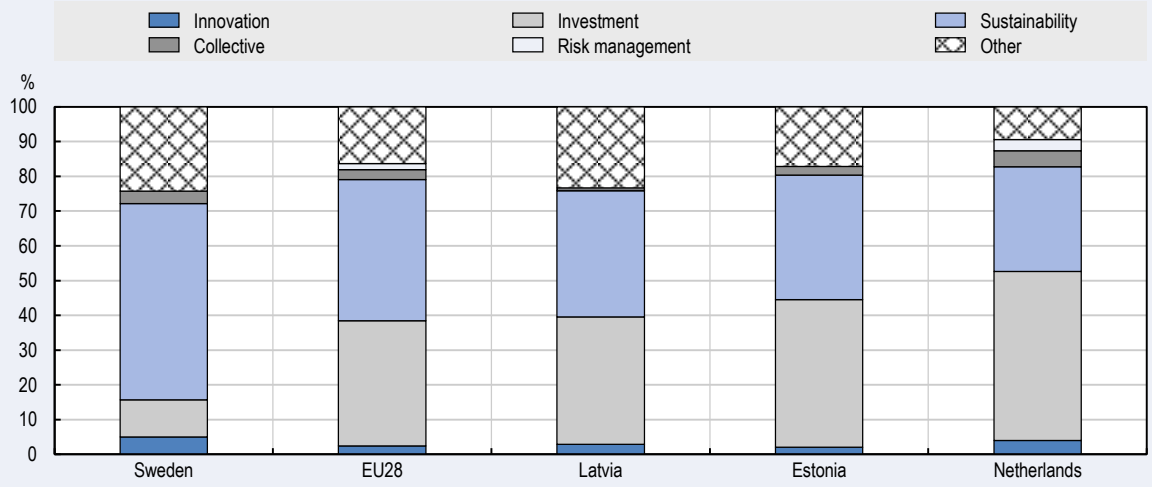
Knowledge transfer measures cover arrangement of training activities, arrangement of demonstration and information activities, arrangement of visits to enterprises and study groups, and long-term programmes (M01), as well as support to individual advisory services and support for training advisors (M02).

Collective actions also have a direct link to innovation through the funding of participation in innovation clusters, and the development of value chains and local markets, which can be considered as marketing innovation, and the activities of producer organisations in these areas.

Figure 4.4 compares the choices of reviewed EU Member States in the RDP 2014-20. The largest share of RDP funding is for investment support in Estonia and the Netherlands, while Sweden dedicates more than half of RDP budget to measures enhancing sustainability and animal welfare. The share of innovation-related measures is small but larger than EU average in the Netherlands and Sweden.

Source: OECD (2018c), *Innovation, Agricultural Productivity and Sustainability in Estonia*, https://dx.doi.org/10.1787/9789264288744-en.

Figure 4.4. RDP 2014-20 choices by reviewed EU Member States



Note: Countries are ranked according to Investment levels. Innovation includes Measures 01 and 02; Investment is the sum of Measures 04, 05, 06 and 08; Sustainability is the sum of Measures 10, 11, 12, 13 and 15; Collective actions are Measures 09 and 16; and Risk management is Measure 17.
Source: European Commission (2015), Factsheet on 2014-2020 Rural Development Programme for Estonia, https://ec.europa.eu/agriculture/rural-development-2014-2020/country-files/ee/factsheet_en.pdf.

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Structural adjustment is mainly driven by market incentives as farmers want to benefit from economies of scale to become more competitive. In countries where the regulatory and policy environment does not prevent adjustment, farm consolidation has been rapid. This is, for example, the case in Australia, Brazil, most sectors in Canada, and the United States, but also the reviewed EU Member States, in particular Estonia where land is relatively abundant. Conversely, in Asian countries, land scarcity and restrictions on land use and markets have hindered the adjustment needed to improve productivity and sustainability. Efforts are being made, however, to improve the functioning of land markets, in part to respond to the shortage of labour in the sector. Policies to improve land consolidation in China are summarised in Box 4.3.

High support levels also contributed to slowing structural adjustment in some countries and for some commodities, and distorting resource allocation. Production quotas are particularly constraining, depending on implementation mechanisms. Even if tradeable, production quotas can still be constraining as they make farm expansion and setting-up more costly. EU dairy production quotas have been gradually abandoned, which has permitted increases in dairy production and farm size in Estonia and the Netherlands (Kimura and Sauer, 2015). Switzerland also abandoned dairy quotas in 2009. However, supply management remains in Canada for three commodity sectors, including dairy, and marketing orders remain in the United States for milk and more than 20 fruits and vegetables, but constrain production volumes of only one product (tart cherries). The EU sugar quota system ended in 2017. In the United States, marketing quotas appear to have restricted structural change and productivity growth, given the sharp changes that occurred after the quotas were eliminated for peanuts and tobacco (MacDonald, Korb, and Hoppe, 2013).The US sugar programme retains 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.

At the same time, countries where the main policies have slowed structural change implement specific policy measures to facilitate the transition to a new generation of more innovative and productive farmers through early retirement schemes and the provision of specific or higher support to younger farmers. This is in particular the case in EU Member States. In other cases, structural adjustment packages accompanied reform, for example in Australia with the dairy reform; and in the European Union with the 2006 sugar reform, which included a two-year voluntary restructuring scheme, with funds available for processing factory closure, assistance to sugar beet growers, diversification measures, and transition measures (Box 6.2 in OECD, 2007).

Box 4.3. Policies to facilitate land use consolidation in China

Consolidating small and fragmented farm operations into large-scale units is one of the most important pathways of improving productivity growth and sustainability of agriculture in China.

China aims to exploit the leading role of diverse forms of large-scale operations, promoting the consolidation of land resources to new agricultural operation entities including family farms, farming service providers and co-operatives. The diverse formats of land use consolidation have the advantage of being flexible in adapting to the local conditions and can facilitate more rapid structural change than a simple transaction of land use rights between individual farmers.

The new co-operative organisation emerged in the late 1980s as a voluntary organisation of farmers to disseminate agricultural technology and carry out marketing activities. For example,

Farmer Professional Co-operatives (FPC) play key roles for small-scale family farms to adopt technology, integrate with supply chains and benefit from economy of scale in farm operation. FPC services typically include technical training, processing, marketing and purchasing inputs. The co-operatives often function as a broker of technologies through sharing information and providing advisory and training services. In other cases, the co-operatives allow smallholder farms to obtain more competitive prices in input and output markets through increasing their bargaining power. Land Shareholding Co-operatives (LSC) is an emerging type of co-operative which allows a group of farmers to put in trusts their land operational rights and receive dividends every year according to their share.

The development of farm machinery services in China contributed greatly to the mechanisation of major farming tasks in China. The use of farm machinery service providers allows small-scale farmers to save their labour input and to avoid a large capital investment and maintenance costs associated with farm-owned machines.

The government supports the development of co-operatives as a new type of farm management unit. In addition to providing a legal status and standard operational rules for the farmers' co-operatives, the government is increasing direct support to them. For example, it provides them with financial and technical support through preferential treatment for value-added tax and stamp duties, credit guarantees and personnel training.

Source: OECD (2018d), *Innovation, Agricultural Productivity and Sustainability in China*, https://doi.org/10.1787/9789264085299-en.

Risk management is essential to improve adoption of innovation and more sustainable practices that could increase risk exposure (OECD, 2015a). However, care should be taken that support to risk management instruments does not encourage unsustainable behaviour.

All policy measures that increase income help farmers manage risk to some extent, through savings and investment in income diversification, investment in risk-reducing technologies, and if provided as fixed payments, by reducing relative income fluctuations (OECD, 2009). This is in particular the case for single payments in EU countries, which cushion variations in market receipts. Moreover, investment support can facilitate the adoption of risk reducing technologies and practices, such as buildings improving health and welfare conditions of farm animals, or on-farm storage facilities.

Most reviewed countries also provide more direct risk management support. This can be in the form of a direct payment conditional or based on a reduction in farm receipts, at individual or regional levels, linked to specific current of fixed areas, commodities or group of commodities. These have been most important in US and Canadian agricultural policies. Korea introduced a variable payment for rice in 2005.

Subsidising crop insurance schemes has been a traditional way to help farmers manage crop risks in Canada and the United States. Crop insurance subsidies are also an important part of support to Brazilian agriculture. Other reviewed countries also offer such insurance programmes, as well as support to mutual funds to compensate for losses, but to a much smaller extent. For example, in Estonia, participation in insurance for livestock has been low, partly because the support is not attractive, and no insurance company offered crop insurance, which could also benefit from subsidies. In other EU Member States, the uptake of risk management support under the Rural Development Programme has also been limited.

As support to crop insurance is based on current parameters, it is expected to encourage higher input use to maximise profit, which can in turn increase resource and environmental

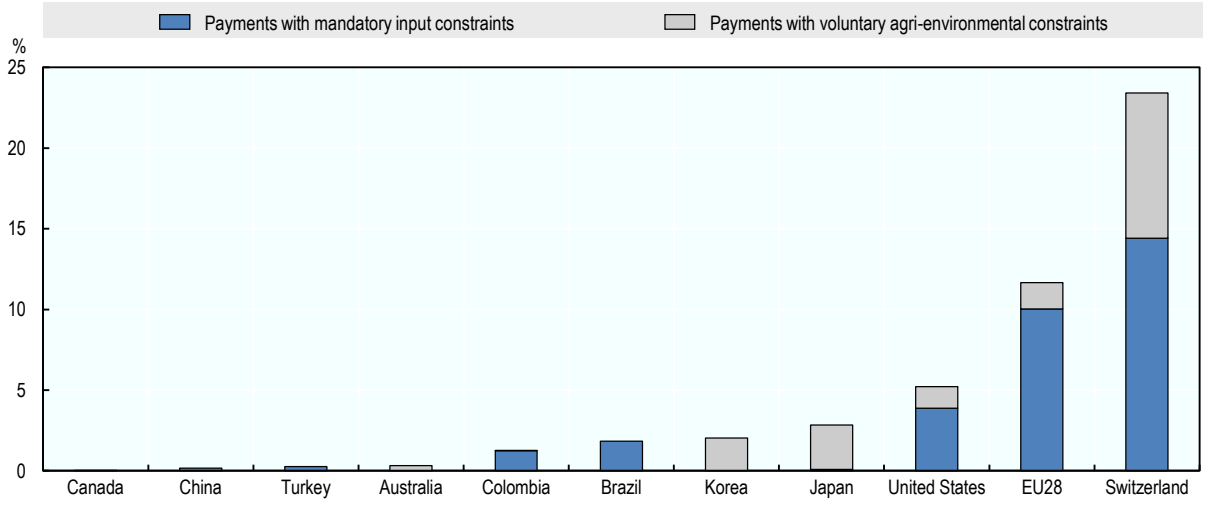
pressures. It could also encourage farmers to undertake risky behaviour, and thereby be inconsistent with climate change adaptation objectives. In non-catastrophic risk setting, they could distort insurance markets and encourage the use of crops not adapted with a changing climate (Ignaciuk, 2015; OECD, 2016b).[3] Empirical analyses on US programmes find very small effects of crop insurance subsidies on total land use, but some suggest a non-negligible impact on crop rotation, and variable input use (OECD, 2017b).

In Australia, most support, which is low compared to other OECD countries, is to help farmers manage risk, which includes drought. Drawing from experience with former programmes (Box 6.1 in OECD, 2015c), catastrophic risk has been more clearly defined and the Agricultural Competitiveness White Paper (Australian Government, 2016) suggests measures to help farmers be better prepared in the face of risk in addition to support measures to help cope with the consequences of risk, giving more responsibility to farmers in deciding how to use support. Direct support is also provided to upgrade on-farm infrastructure and irrigation efficiency with the aim of improving natural resource use and environmental management.[4] Tax concessions form part of the policy approach aimed at helping producers manage production and market risk through allowing them to smooth their incomes, and also provide further incentives for on-farm preparedness-related investments (OECD, 2015c). In Sweden, farmers are usually covered by normal insurance schemes (OECD, 2018e).

Agricultural policies include two broad types of economic incentives encouraging the **adoption of more environmentally-friendly practices**: mandatory cross compliance applying to most payments and specific payments based on voluntary participation in agri-environmental schemes. As shown in Figure 4.5, these support programmes vary in scope but remained under 5% of total gross farm receipts in most reviewed countries.

Figure 4.5. Support conditional on the adoption of specific production practices, 2015-17

Percentage of gross farm receipts



Source: OECD (2018a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), https://dx.doi.org/10.1787/agr-pcse-data-en.

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More specifically, there is a wide range of agri-environmental and natural resources policy approaches, depending on the type of problems. Some countries rely heavily on positive incentives, other on regulatory constraints, few on market-based mechanisms. For instance, Brazil's Low Carbon Agriculture (ABC) Plan provides loans to support conservation practices, or the restauration of pastures. The Environmental Farm Plans programme in Canada supports environmental assessments of farm practices on specific farms that are then eligible for the cost shared financial assistance programme (the Environmental Stewardship Incentive programme). Sweden was one of the first countries worldwide that introduced taxes on pesticides. Combined with other policy measures on pesticide registration and application, and measures encouraging integrated pest management, the tax contributed to a reduction of more than 50% of pesticide sales nationally, and a large decrease in pesticide risks for human health and to the environment. Sweden also requires an environmental impact assessment for a wide range of agricultural activities, in particular, for intensive livestock production; the cost of the assessment is borne by farmers (OECD, 2018e). The Netherlands has introduced a charge (since 2013) for the Storage of Sustainable Energy (ODE) in addition to the standard tax on energy (EB). A low tax rate has been agreed for heating used to assist the growth of horticultural products, but the sector will have to pay for exceeding the CO_2 emissions target agreed with the government. The country also applies a performing regulatory programme to curb nutrient runoff from agriculture (OECD, 2015d). The United States has implemented a federal regulation on manure management of large cattle operations that has also shown to be effective (OECD, 2016a).

While there remain significant gaps in the literature, a range of studies has attempted to evaluate the environmental impacts and effectiveness of agri-environmental policies. An OECD study reviewing the literature showed in particular that action-oriented (also called practice-based) agri-environmental measures often performed more poorly than result-oriented measures (OECD, 2019d). Results-oriented agri-environmental policies are considered to have the potential to stimulate on-farm innovation and adaptation of environmental management practices to local conditions. However, empirical evidence on the degree to which results-oriented mechanisms spur innovation is scant, not least because results-oriented mechanisms are still in their infancy.

US conservation policies have been among the most studied thanks to robust data collection and rigorous analyses. The development of cross-compliance and voluntary conservation programmes in the United States has partly contributed to reduce soil erosion and environmental impacts of agriculture since the 1980s (see Box 4.4 on the Conservation Reserve Program). 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 out such as technology, information and markets (OECD, 2016a).

Despite these encouraging results, there are still several issues and challenges regarding the design and performance of US agri-environmental programmes. First, there exists evidence that sustainability performances could be further improved, in particular in terms of 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. Second, additionality of conservation programmes may be lower for certain practices. Third, 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”. Fourth, targeting and tailoring mechanisms such as the Environmental Benefit Index could be further refined and expanded. Fifth, 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 (OECD, 2016a).

Fewer studies yet have looked at the impact of agri-environmental policies on productivity. Results from a farm-level simulation model built to study the policy synergies and trade-offs between climate change adaptation, mitigation and productivity in agriculture suggests that context may matter; the same instrument may have positive or negative productivity effect in the US Midwest or Finland (Lankoski, Ignaciuk and Jésus, 2018). In its literature reviews, OECD (2019b) found that there are mixed impacts, finding cases where agri-environmental payments can have positive or negative effects on productivity.[5]

Box 4.4. The US Conservation Reserve Program (CRP): Competitive tendering based on an environmental performance index

The Conservation Reserve Program (CRP) of the United States provides 10-to-15-year contracts to remove land from agricultural production and place it under grass or tree cover. CRP enrolees can choose from a menu of farm practices (establishment of permanent native grasses, tree planting, riparian buffers, field-edge filter strips, etc.) that provide permanent grassland, reforestation, wetland restoration, and wildlife habitat. CRP enrolees receive land rental payments, and additional payments reflecting a share of the costs of installing various conserving practices on their land.

Although the programme is based on a predefined list of activities and practices, it provides funding proportional to expected environmental performance. Whole-field and whole-farm CRP expenditures are awarded on the basis of *ex ante* expected environmental benefits. Increasingly, CRP funds have been reoriented to support high-value partial field land retirements.

Enrolment is competitive. Competition for participation is generally managed through a bidding process. In most cases, eligible producers submit offers for participation, specifying the CRP 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 an ex ante estimation of 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 (EBI), 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. The EBI thus helps assure that programme funds are used most effectively.

Sources: OECD (2017a), "Evaluation of farm programmes in the 2014 US Farm Bill: a review of the literature", https://dx.doi.org/10.1787/ff39e390-en. USDA (2017), Conservation Reserve Program website, www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index (accessed 21 June 2017).

Policies regarding climate change are often managed outside of the agriculture sector, but reviewed countries have introduced programmes supporting adaptation to climate change or the mitigation of the sector's GHG. A recent assessment showed that while all OECD countries have developed policies in the agricultural sector that support adaptation to climate change, progress on the specification of national (and subnational) adaptation strategies varies widely across countries and implementation is still limited (Ignaciuk, 2015). Examples of programmes in reviewed countries include the Delta Programme in the Netherlands, aiming at redesigning flood risk management, including agricultural land areas, and the USDA Regional Climate Hub initiative which provides tailored made

information for advisory services in agriculture and forestry on projected climate change risks in different parts of the country (OECD, 2017b).

Efforts have been less systematic on GHG mitigation, as countries continue to be developing policies. Australia has introduced the Emission Reduction Fund (ERF), which attributes funding to the most cost-effective bidders to reduce GHG emissions. While eligible to other sectors, agriculture is one of the key sectors targeted by the initiative. The Korean government excluded agriculture from its emission trading system, just like other OECD countries so far.[6] But it has engaged in other initiatives, including the provision of cost-share investments into livestock manure treatment facilities that recycle livestock manure into usable fertilisers (OECD, 2018f). The Dutch programme Greenhouse as Energy Source (*Kas als Energiebron*) was launched in 2005 with the aims to make all new greenhouses climate-neutral and economically profitable from 2020 onwards (Box 2.2 in OECD, 2015d).[7]

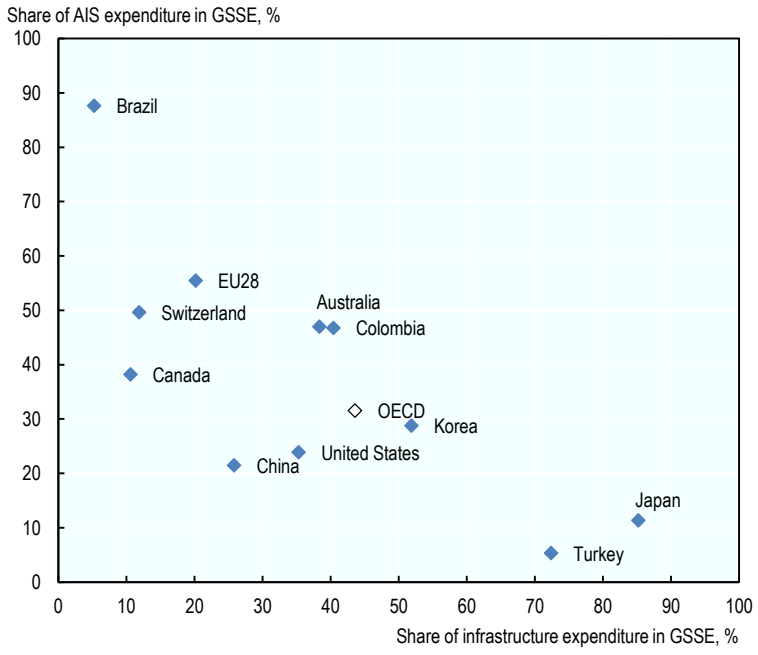
General services are key to improving long-term performance of food and agriculture

Providing general services to the sector is more efficient than support to individual producers to enhance the long-term competitiveness of the food and agriculture sector. The GSSE includes policies that directly affect innovation and thus sustainable productivity, such as public expenditures for agricultural R&D and advisory services (Chapter 4). It also includes government expenditure on inspection and infrastructure, which are considered as part of the policy environment enabling innovation, productivity and sustainability in food and agriculture (Chapter 5). Other general services such as support to marketing and promotion, and public stockholding, are not considered as enabling productivity growth.

Brazil appears as the country with the largest share of innovation-related expenditure in the GSSE (Figure 4.6). This is consistent with the dominant role the public agricultural research organisation, Embrapa, plays in Brazilian agricultural and at the international level, but also the relative lack of infrastructure. The European Union (mainly as part of national expenditure), Switzerland, Australia and Colombia — countries with very different levels of support to producers — dedicate close to 50% of their expenditure on general services to the agricultural innovation system. In contrast, Japan and Turkey invest a considerably higher share of their expenditure on general services in agriculture-related infrastructure.

Figure 4.6. Focus of general services support, 2015-17

Share of expenditure on agricultural innovation and on infrastructure in the General Services Support Estimate (GSSE)



Notes: Agricultural Innovation System (AIS), including R&D, agricultural schools and advisory services. The OECD total does not include the non-OECD EU Member States.
Source: OECD (2018a), "Producer and Consumer Support Estimates", OECD Agriculture statistics (database), https://dx.doi.org/10.1787/agr-pcse-data-en.

StatLink https://doi.org/10.1787/888933998652

Main knowledge gaps

The OECD database on support to agriculture contains a lot of useful information on agricultural policies, comparable across countries. For this exercise, broader coverage of the whole food system, bioeconomy and rural economy would be useful, in particular for general services.

In many countries, income support is a major objective of agricultural policies. However, information on the income and wealth of farm families is often incomplete, and not comparable to that of other households for tax purposes. This makes it difficult to address income issues in farming in an equitable way via social policies.

Information asymmetry between farmers and the government also makes it difficult to identify potential market failures in the provision of credit, risk management tools or public goods demanded by society. Consequently, governments do not have enough information to design efficient policies.

Evidence on the impact of specific agricultural policy measures on the productivity and environmental performance of the sector remains limited.

Recommendations on agricultural policies

This section consolidates recommendations for agricultural policies made in country reviews, which are detailed in the country notes of Annex B.

Adopt a food and agricultural system strategy

- Identify deficiencies in the value chain and design appropriate incentives to address them, including within the scope of agricultural policy.
- Develop further digital solutions to collect and manage data, reduce control costs, and to improve traceability along the food chain.

Focus agricultural policy on the sector's long-term development objectives

- Move towards measures to improve the sector's long-term productivity and sustainability, such as investment in general services that strengthen human and infrastructure capacity, and farmers' connection to input and output markets. These services include various forms of sector-specific hard and soft infrastructure, appropriate biosecurity efforts, and agricultural innovation systems responsive to needs (as discussed in Chapter 6).
- Develop a long-term vision reconciling productivity and sustainability improvements to reduce policy uncertainty and contradictory policy signals.
- Reduce the relative importance of government support in agricultural incomes and increase the share of farmers' returns from the market.

Strengthen capacity to respond to future challenges and opportunities

- Ensure that environmental and climate change concerns are taken into account when developing and evaluating policies that can contribute to productivity and competitiveness.
- Improve preparedness of farmers and adaptation to climate change.
- Review current policies to test their capacity to respond to future challenges and opportunities (i.e. higher frequency of natural disasters and risk management tools, new pest and diseases, change in water management needs, etc.)
- Explore options for reducing GHG emissions from agriculture, in particular grazing livestock, facilitate farmers' adaptation and initiate relevant research.

Better information for better agricultural policies

- Improve or maintain a good information base and analytical capacity to monitor policy implementation, 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 to facilitate benchmarking and knowledge sharing.
- 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.

- Better link agricultural policies to clear objectives to facilitate policy evaluation and reduce policy uncertainty.

Identify market and policy failures when providing support to producers

- Investigate or revisit the extent and causes of market failures, and their impact on investment and resource use to adapt policies to new issues.
- Improve information on income levels and variability in agriculture to allow the government to design better-targeted policies. Take steps to induce farmers to declare their income situation.
- Evaluate farmers' access to credit, and whether lack of access is linked to specific, individual circumstances, or general failure in the sector or in the credit market, to design the appropriate level of intervention.
- Improve information on risk exposure, farmers' risk perceptions and use of risk management tools, and the impact of these factors on willingness to invest.
- Explore the impact of policy measures on innovation, structural change, natural resource use and climate change.

Reduce agricultural policy distortions

- Reduce support levels, minimise support that distorts agricultural commodity markets and trade, and reduce variations in support level across commodities to enhance reallocation of resources based on market demand. This should provide opportunities to take advantage of growing and more diverse demand, in particular for high value products. In particular:
  - Eliminate domestic price support measures, such as border protection and commodity-specific support, and consider introducing direct payments to facilitate the transition, if needed.
  - Remove measures that reduce the cost of specific variable farm inputs, without imposing environmental constraints.
  - Limit the provision of coupled payments to very targeted and temporary measures.
  - Reduce transfers to state economic enterprises and agricultural co-operatives that distort competition.

Remove impediments to innovation, structural change and sustainable resource use

- Move away from measures and compliance conditions that discourage innovation.
- Remove impediments or disincentives to structural adjustment and the realisation of scale economies that may exist in the land and labour markets.
- Minimise policy incentives to unsustainable use of resource from measures pursuing other objectives.

Harness agricultural policy measures to target more precisely productivity and sustainability drivers

- Focus agricultural policy to support innovation, structural change, sustainable resource use and climate change adaptation in areas where markets fail to send a signal to farmers to adapt.
- Improve the targeting of measures designed to pursue these objectives.

Provide more specific incentives to innovation and adjustment

- Target innovation directly, using dedicated incentives within investment support, service provision, or payments for the adoption of new production and marketing practices.
- Support investments into the modernisation and restructuring of farm and agri-food firms and the uptake of new technologies, including digital-based opportunities.
- Support diversification of activities.
- Use agricultural policy to support collaborative activities and participation of farmers or farmers' representatives in knowledge networks.

Strengthen incentives to sustainable use of natural resources

- Strengthen the ability of agricultural policy to improve the environmental performance of agriculture, by improving the design of agri-environmental programmes, using best available scientific and economic evidence basis to better target and tailor to actual needs.
  - Establish a framework of agri-environmental policies, which clarifies the reference environmental quality levels as well as environmental targets
  - Encourage performance-based evaluation of policies and implement measurable indicators of performance. Explore the scope for using digital technologies for monitoring outcomes, possibly through pilot programmes.
  - Revisit the balance between regulation and economic incentives in view of fostering environmentally-friendly innovation.
  - Increase the scope of the polluter-pays-principle to hold farmers accountable for harmful environmental effects from crop and livestock pollution, while raising funds for more ambitious agri-environmental targets where appropriate.
  - Consider market-based approaches to further reduce environmental pressure and the development of environmental service markets, such as carbon offsets and water quality credit markets.
  - Take a multi-dimensional approach to manure management, including regulation, incentives to invest in new technology, capacity-building of producers and building partnerships between stakeholders.
  - Strengthen efforts to provide targeted and tailored advice to farmers on sustainable technologies and practices.
- Improve the overall efficiency of agriculture water use at the river basin level by combining a flexible and robust water allocation regime, cost-effective and targeted

investments in water storing infrastructure and irrigation, and self-financing mechanisms to ensure the viability of irrigation systems.

- Integrate climate change adaptation and mitigation as a cross-cutting aspect of agricultural and agri-environmental policies
- In countries where agri-environmental policy is designed at the local level, strengthen the role of the federal government to co-ordinate 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.

Promote farmers' preparedness and risk management to facilitate future investment

- Review and improve risk management tools (if needed), focusing government role on preparedness, provision of information and catastrophic risk.
- Consider an assessment of existing subsidised agricultural insurance, with regard to its longer-term financial and actuarial soundness and in view of climate change risk.
- 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.·

Better target investment support to needs

- Assess investment needs and enhance the effectiveness of public investment support by focusing on areas where financial markets fail to provide funds for the provision of public goods, and better integrate business advice and synergies with research and innovation.
- Streamlining programmes and simplifying access procedures, if this is an issue.
- If needed, increase the role of rural credit institutions in financing farm capital investment.
- Further promote the development of private non-bank financial instruments for agriculture and agro-industries, subject to a review of existing instruments.
- Enhance criteria for loan eligibility to better screen out borrowers that would have invested without support.
- Focus concessional investment credit on projects that explicitly incorporate technological innovations, and advanced farm management and environmental practices.
- Adapt credit support rate to needs, without encouraging unsustainable investment in equipment.

Better account for the diversity of the farm population

- Adapt programmes to different farm population needs, e.g. small, subsistence farms versus commercial farmers.
- Review the situation of small, semi-subsistence farmers and address their specific needs using a wider range of policy approaches.

Pursue wider objectives with non-sectoral policy

- Address policy and market failures that are not specific to agriculture at the level they occur, and do not use agricultural policy. For example, agriculture policy is not the most appropriate to compensate for general failure in the credit market, or address general social or rural development issues.
- For rural development, take a more bottom-up approach to promoting integrated investments and public services that respond to local needs to attract non-agriculture industries to locate in rural areas.
- Consolidate and enhance rural diversification activities across various agencies and within various programmes; consider a co-ordinated national rural diversification framework that focuses on the development of rural industries; increase the emphasis on rural diversification in regional and rural development investments.
- Increase the role of general social security system as an income safety net for farm households by introducing adjusted eligibility criteria and additional incentives for early retirement and resource transfer to young commercial farmers.

Notes

[1] Estonia, Latvia, the Netherlands and Sweden are all represented by the EU28 in Figure 4.1.

[2] OECD (2013) identified the potentially most environmentally harmful support categories as market price support; payments based on commodity output, without imposing environmental constraints on farming practices; and payments based on variable input use, without imposing environmental constraints on farming practices. OECD work has analysed the environmental impacts of these support mechanisms using market level and farm level *ex ante* simulation (Henderson and Lankoski, 2019).

[3] For instance, Annan and Schlenker (2015) find that American farmers with insurance opt for more heat sensitive crops and do not have the incentive to engage into adaptation.

[4] There are questions, however, on the actual saving realised by irrigation efficiency investments (Grafton et al., 2018).

[5] The review of literature also found that agri-environmental policies tend to decelerate the pace of structural change by allowing land retirement, fallow or low-management land uses to become a (more) profitable land use option for farmers.

[6] At the subnational level, the Canadian province of Alberta allows industries and organisations with GHG mitigation obligations to purchase emission reduction credits from agriculture producers (OECD, 2019c). The US State of California also allows the purchase of carbon offsets for methane reduction in livestock operations and in rice cultivation (see www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm).

[7] See www.kasalsenergiebron.nl/over-ons/kas-als-energiebron/ for more information on the Greenhouse as Energy Source programme.

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Chapter 5. Innovation policy and the agricultural innovation system

This chapter provides an overview of agricultural innovation systems in the reviewed countries. It outlines their diversity in terms of actors, ambitions, governance, funding mechanisms, incentives to invest and collaborate in research and innovation, and mechanisms to encourage adoption, including farm advisory systems. It also acknowledges efforts to improve the impact of public expenditure and make the system more collaborative and demand driven to increase relevance and thus adoption. Finally, it identifies main knowledge gaps in this area and consolidates recommendations to strengthen agricultural innovation systems made in country reviews.

- Agricultural innovation systems in reviewed countries differ in terms of ambitions, size and institutions. There is no one size fits all.
- One important trend in innovation policy is to improve the impact of public expenditure and make the system more collaborative and demand driven to increase relevance and thus adoption. However, top-down approaches continue to dominate in most countries.
- Efforts to improve the governance of the agricultural innovation system focus on developing more coherent and longer term strategies for innovation in food and agriculture, involving stakeholders more formally and from earlier stages, and strengthening evaluation frameworks.
  - Efforts to integrate farmers in the innovation process are growing in some countries.
  - Better information is needed to improve evaluation of research and facilitate priority setting.
- Agricultural research is changing but remains dominated by the public sector in most reviewed countries, while private research traditionally focuses on specific sectors like genetic improvements, fertilisers and chemicals, buildings and machineries, and food processing.
  - Various trends in public funding for agricultural research are found across countries: they decreased in the last 15 years in major exporting countries like Canada, the United States and the Netherlands; but increased in several other countries.
  - Research funding mechanisms also change, with the development of competitive project funding.
  - Government support research and innovation in firms through investment support and tax rebates, and by enforcing Intellectual Property Rights.
- Efforts to foster public-private collaboration have been made in most countries, but the capacity of local agri-food companies to engage in research activities remains often limited.
- International co-operation is important for countries of all sizes, to reduce costs and pool resources and exploit synergies on regional or global challenges. It is most developed among EU Member States.
- Renewed policy attention is paid on improving the adoption of innovation in farms and firms, through improvements in the enabling environment, and specific investment support.
- Farm advisory systems play an important role in innovation. They are in transition to adapt to new needs and provide a wider range of advice requiring re-training and flexibility. New intermediary actors emerge to meet these needs.

Diversity of actors and systems

Agricultural innovation systems involve a wide range of actors, including policy-makers, researchers, teachers, advisors, farmers, private companies, non-profit organisations, and consumers.

In most countries, governments provide strategic guidance for research and innovation, and provide funding to research institutions, private companies, and advisory systems. Government funding can be granted directly to research institutions, or through funding organisations, such as research councils or foundations, which allocate funds to projects. Depending on the country, part or all of agricultural research funding is integrated into the general innovation policy.

In several countries, the Ministry in charge of agriculture plays a prominent role in funding and performing agricultural research via agricultural research institutes that are part or under the umbrella of the ministry (e.g. INTA in Argentina, Embrapa in Brazil, Agriculture and Agri-Food Canada's research centres, Corpoica in Colombia, and the USDA Agricultural Research Service). These research institutes include regional offices and laboratories throughout the country, and are often active in knowledge diffusion.

Beside government research centres, universities in these countries also perform agricultural research and development (R&D), and have a significant role as in the case of land-grant universities the United States. They often focus their activities on regional agricultural strengths, and receive both federal and regional funds.

In the reviewed EU countries, agricultural R&D is funded as part of general R&D mechanisms, but performed mainly in universities with strong specialisation in agriculture or life sciences (University of Life Sciences in Estonia, Latvia University of Life Science and Technologies, Wageningen University in the Netherlands, and the University of Agricultural Science in Sweden). In Estonia, Latvia and the Netherlands, the agricultural university includes applied research institutes (e.g. Wageningen Economic Research). In Turkey, 43 universities are engaged in agricultural R&D, as well as two of the TÜBITAK institutes.[1]

Diversity is even higher among advisory systems, from competitive ones with a large range of suppliers for farmers to choose from, and minor government involvement, like in the Netherlands, to comprehensive government managed and funded systems like in Korea. In Brazil, the public advisory system focuses on non-commercial, smaller farmers.

Input industries play a large role in R&D for agriculture, in particular to improve variable inputs — seeds, fertilisers, pesticides, veterinary medicine — as well as farm machineries and equipment. However, these are relatively concentrated industries, which perform research in few, large countries. Some food processing companies are also active, but many lack capacity for research. Both upstream and downstream industries contribute to knowledge transfer. Increasingly, new companies emerge to provide specialised advice and services to farmers on new technologies. This is in particular the case with application of digital technologies to the sector (OECD, 2019b).

Governance of agricultural innovation systems

In all reviewed countries, strategic plans over five to seven years are developed for agriculture and food research, often as part of national science technology and innovation (STI) strategies and in co-ordination between STI and agriculture-related ministries. In this

framework, research organisations develop their own objectives. In countries with a diversity of public research organisations such as Canada, the People's Republic of China (hereafter "China"), Turkey and the United States, co-ordination is all the more important. An important recommendation in many reviews (e.g. the Netherlands and Sweden) was to define long-term objectives for R&D and innovation. The Netherlands has translated this into the development of a strategic knowledge and innovation agenda. Social issues are central to this agenda and will be implemented through multi-year mission-driven innovation programmes. Together, the government and stakeholders are defining concrete goals that will be pursued with a wide range of policy instruments.

Productivity growth remains an important objective of agricultural innovation systems in many countries, but the range of objectives has generally broadened to include sustainability and climate change issues, food and health and other societal issues. The new emphasis on more complex issues requires multidisciplinary and multi-sectoral approaches, thus the need to reinforce co-operation between researchers and research organisations. A particular challenge is to adopt a longer term perspective for long term challenges, such as climate change.

In defining objectives and allocating funding, it is particularly important to define clearly the respective roles of the public and private sectors, and areas of mutual interest and possible co-operation. An analysis of public and private R&D activities in the United States suggests there is complementarity, with public research focusing on different specific topics than private, and that private often building on the scientific findings of public research. It is less clear in countries with lower private investment in research, often linked to a market size too small to attract multinational companies or low capacity of national companies.

In most countries, approaches to agricultural innovation remain mainly top-down although efforts are increasing to better understand innovation needs and to strengthen participation of stakeholders, including in the definition of strategies and objectives. In a few countries, formal institutions have been created to facilitate discussion and co-operation throughout the innovation process. This is in particular the case in Canada with the Value Chain Round Tables (Box 5.1), in the Netherlands with the creation of Top Consortia as part of the implementation of the Top Sector Policy (Box 5.4), and in Australia with the Research and Development Corporations (RDCs) (Box 5.5). A further challenge is to ensure a wider representation of stakeholders, which would include the diversity of sectoral and societal interests.

In many countries, innovation is taking place within specific value chains. Argentina and Colombia provide examples of very successful value-chains investing in research and innovation, co-existing with less efficient ones.

Box 5.1. Value Chain Round Tables in Canada

Twelve Value Chain Round Tables (VCRTs) have been launched in 2003 to facilitate co-operation across the supply chains at the national level. Bringing together key industry leaders from across the value chain – input suppliers, producers, processors, food service industries, retailers, traders and associations (geographical regions and sector diversity are also considered) — with federal and provincial government policy makers, VCRTs have become central vehicles for: identifying sector strengths and weakness; capitalising on domestic and international market opportunities; sharing information and building trust across commodity sectors; identifying research, policy, regulatory and technical requirements; creating shared visions and co-operative long-term strategies; and responding to crises.

Source: OECD (2015a), Innovation, Agricultural Productivity and Sustainability in Canada, https://dx.doi.org/10.1787/9789264238541-en.

Evaluation of research and innovation policy is important to increase the efficiency with which public funds are used, and more broadly to improve the functioning of the research and innovation system and its contribution to addressing a wide range of socio-economic and environmental issues and to global challenges (Joly et al., 2016). Practices are very diverse among reviewed countries, and evaluation is often partial, focusing on financial considerations (Table 5.1). Research excellence is the main criteria for the evaluation of researchers, projects and institutions. As a result, networking and knowledge transfer activities, which increase impact, are not valued. In many countries, innovation policy or research organisations are at minimum assessed with regard to set objectives. Latvia requires for example international assessment of institutions. In the Netherlands, research institutions and top sectors evaluate their activities annually. In addition, an independent review is required every five years, based on quality of research.

Evaluation of research projects and researchers is also common practice. In the evaluation of researchers or research units, research excellence validated by scientific peers is the main objective. While this criterion is recognised at the international level, other types of incentives are needed to ensure better integration in the agricultural innovation system. Project evaluation responds to criteria set for project selection, and increasingly includes ex ante and ex post impact assessment.

Evaluation is often left to research organisations. Embrapa in Brazil estimates returns on investment. In Australia, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) used independent assessment (e.g. ACIL-Allen Consulting, 2014), including estimation of returns on investment, to develop a new strategy and develop a common framework for all impact assessments within CSIRO. These guidelines notably develop a programme logic based on input-outcome-impact model. It is suggested to broaden the dimensions of impacts considered, including economy, environment and society, and to use a mix of methods for investigating the impact, including qualitative, cost-benefit analysis and option values (to account for the externalities) (CSIRO, 2015). Evaluation in the USDA Agricultural Research Service (ARS) is based on performance targets established in the 17 National Programmes. Most targets are on providing research outputs, but a few targets concern research outcomes or economic and environmental impacts. Both standard economic approaches, which aim to estimate economic benefits of research investments, and case-study approaches, which aim to analyse the processes of impact generation, are applied.

Table 5.1. Type of evaluation of innovation policy

	Basis	Level	Agricultural innovation system
Argentina	Project implementation	Research organisation	No
Australia	Objectives and impact, Returns on investment, environmental indicators being built, larger evaluation every 5 years	Organisations and policy	In development
Brazil	Returns on investment	Research organisation	No
Canada	Programme objectives	Programmes	No
China	..		No
Colombia	Achievements relative to objectives		No
Estonia	Targets of Innovation and agricultural policy	Policy, projects	No
Japan	Objectives in strategic plans and programmes	Policy, projects	No
Korea	Institutional objectives, and research quality	Policy, projects	No
Latvia	Targets of Innovation and agricultural policy international assessment of institutions	Policy, institution, projects	No
Netherlands	Objectives and quality of research, independent review every 5 years	Institutions and top sectors,	No
Sweden	Quality of research	By research institutions	No
Turkey	Planned objectives, quality of research	Projects	No
United States	Objectives and impact assessment, including environmental targets	ARS, projects	No

Note: ..: Not available.
Source: Country reviews; Joly et al. (2016), "Agricultural research impact assessment: Issues, methods and challenges", https://dx.doi.org/10.1787/5339e165-en.

Public funding of agricultural R&D

Public investment on agricultural R&D as a percentage of agricultural value-added (or research intensity) ranges from less than 0.2% in Turkey to over 2.5% in Korea and Switzerland, when measured by Government budget allocation for R&D (GBARD), which includes public funding for R&D on agricultural sciences performed in both public and private organisations (Figure 5.1).[2] Public research intensity is usually higher in agriculture than the overall economy (OECD, 2013).

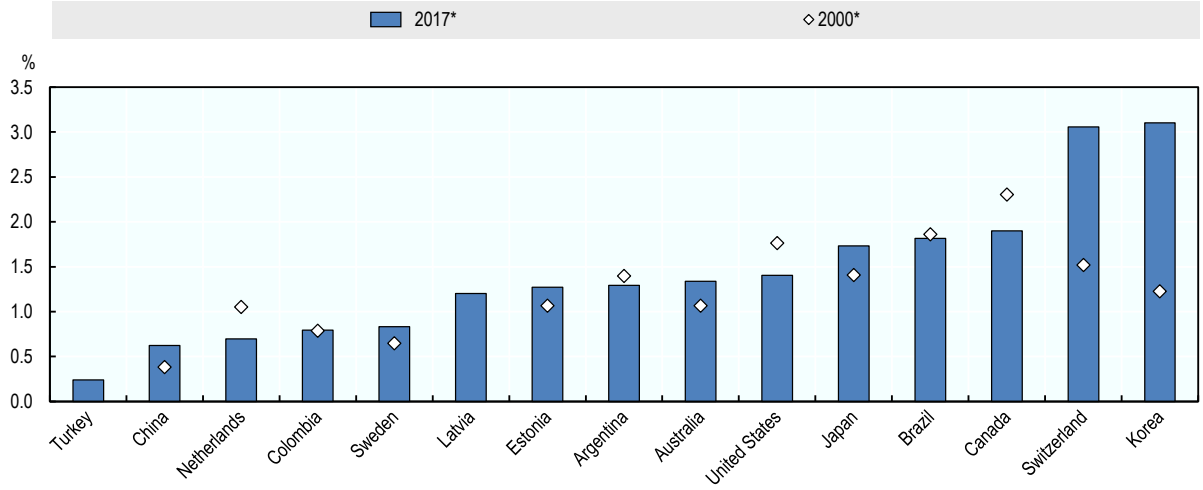
Following significant increases over the period 2000-16, public research intensity is the highest in countries that provide high support levels to their farmers. It is also relatively high in Brazil and Canada which are large competitive exporters, but where private companies often lack capacity to invest in agricultural R&D. Conversely, Australia, the Netherlands and the United States rely to a greater extent on private funding of R&D and research partnerships (see below).

China's government expenditure on agricultural research has increased dramatically since 2000 and overtook US public expenditure in 2009 (in constant PPP USD) (Figure 7.6 in OECD, 2016). As a result, public research intensity has almost doubled in China since 2000, but remains below 1%.

Government expenditure on agriculture research has decreased over time in several major exporting countries (Figure 5.1). This could threaten the capacity of public research to cover areas of less interest to producers (longer-term, public goods) and engage in collaborative activities (e.g. at an international level). In countries with significant private R&D investment, this has not necessarily replaced public investment, as private and public R&D activities are expected to be complementary (OECD, 2016).

Figure 5.1. Public R&D intensity on agricultural sciences, 2000* and 2017*

Government budget allocations for R&D (GBARD)[1] for R&D on agricultural sciences as a percentage of agricultural value added



Notes: * or nearest available year: 2017 is replaced by 2016 for Estonia, Japan, Korea, Latvia, and the United States; by 2015 for Switzerland; by 2014 for Canada; by 2013 for Brazil, China and Colombia. 2000 is replaced by 2002 for Estonia. 2000 data are not available for Turkey and Latvia.

1. Government budget allocations for R&D (GBARD) is a funder-based approach for reporting R&D, which involves identifying all the budget items that may support R&D activities and measuring or estimating their R&D content. It enables linking these budget lines to policy considerations through classification by socioeconomic objectives. However, it provides only a partial indicator of investment in public agricultural research, since it refers to research funding instruments dedicated specifically to agriculture.

Source: OECD (2019a), "Research and Development", OECD Statistics (database), https://stats.oecd.org/ (accessed January 2019); and for Brazil, China and Colombia: ASTI (2017), Agricultural Science and Technology Indicators (database), www.asti.cgiar.org/data (accessed March 2018).

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Public R&D funding mechanisms are changing in an effort to improve relevance of agricultural R&D for the sector and with government objectives reflecting wider societal goals. Governments (and donors) increasingly use project-based, competitive, funding as an efficient way to allocate resources to priority areas. In most countries, governments use both block funding — i.e. research grants to research organisations, often based on past performance, and project-based funding, but to a different extent. In countries with a high share of project-based, competitive funding of R&D, researchers and research institutions experience significant transaction costs and instability.

In Brazil, the main agricultural research organisation under the ministry of agriculture, Embrapa, receives a large share of funds via block funding. At the opposite extreme, most public funds are allocated to competitive projects within top sectors in the Netherlands. Similarly, project-based funding represented over 90% in Estonia over the period 2005-13. However, this raised concerns for long-term strategic planning and sustainability of R&D institutes, and the Estonian Government decided to gradually increase block funding to reach a 50-50 ratio. As a result, the share of block funding reached 20% of the total in 2015 and 27% in 2016. In Sweden the share of block funding has also increased to 45% of university funding in Sweden. Researchers in EU Member States participate in EU funded projects, which in some of them account for a significant share of R&D funding.

In the United States, it is difficult to evaluate the importance of block funding versus project-based funding, but the Agricultural Research Services of the US Department of Agriculture, which receives more than half of Federal expenditure on agricultural R&D, receives mainly block funding. In other reviewed countries, while precise information is not available, but Table 5.4, which attempts to summarise main policy parameters proposes likely ranges based on research organisations and funding institutions.

Private role in food and agricultural R&D

Private investment in food and agriculture R&D is difficult to track in many countries, as it is often missing or incomplete in official statistics. However, estimates of private spending on food and agricultural R&D suggests fast growth in private R&D worldwide, partly in response to higher world prices for some commodities after 2002 (Fuglie et al., 2011; Fuglie, 2016).[3] In particular, there has been a spectacular increase in private investment in agricultural R&D in the United States in recent years. As a result, the share of public funding in the total has declined from around 50% in the early 2000s to 26% in 2014 (Figure 1.20 in OECD, 2018a, OECD, 2016). Private spending on agricultural R&D is mainly located in high-income countries (88% in 2014, compared with 94% in 1990) and highly concentrated in the largest firms.[4]

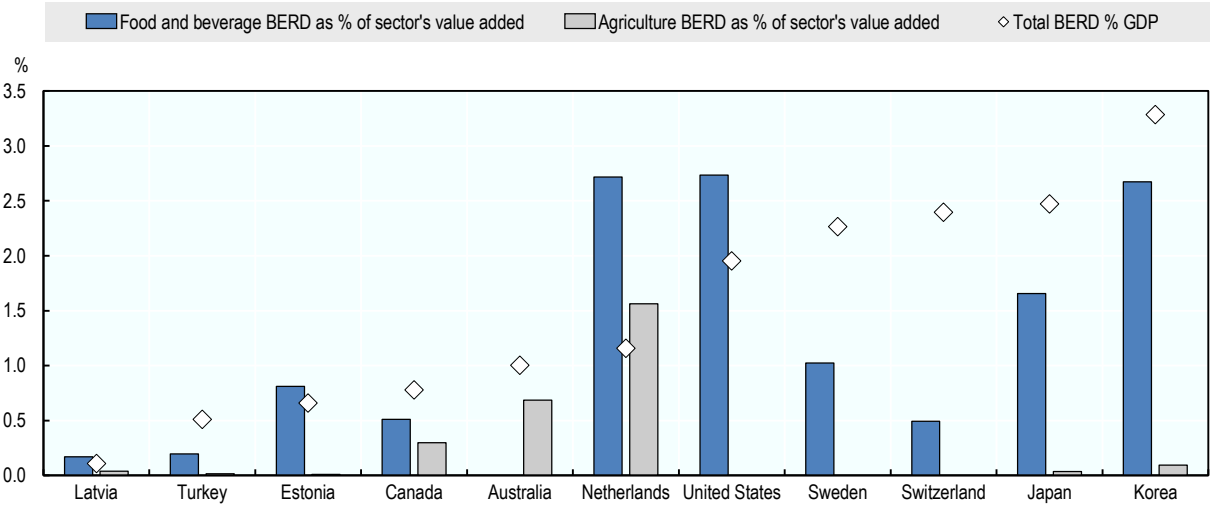
In the Netherlands, the share of private contributions to research projects under the two agriculture-related Top Sectors is about 30% (OECD, 2015b). This is equal to the estimated average share for agriculture R&D at the global level.[5]

Business research intensity for agriculture — as measured by Business Expenditures on R&D (BERD) as a percentage of gross value added — is the highest in the Netherlands, followed by Australia and Canada (Figure 5.2). Although data for the United States are not available in the OECD database, other sources indicate a high business research intensity for agriculture.

Among reviewed countries, research intensity in the food manufacturing industry is the highest in Japan, Korea, the Netherlands, and the United States (Figure 5.2). Day-Rubenstein and Fuglie (2011) find that highest rates are associated with the presence of large multinational companies. In many reviewed countries, national food processing companies often lack size and capacity to do research. This may be due to the cost of doing research locally and the small size of the market, which makes it difficult to develop new markets and products, but also to regulatory burdens and inconsistencies, and particular features of intellectual property protection as applied to rural R&D.

Figure 5.2. Research intensity in the agriculture and food and beverage processing industry, 2016*

Business Expenditures on R&D (BERD)[1] as a percentage of gross value added



Notes: * Or most recent available year; Food and beverage data are not available for Australia; Agriculture data are not available for Sweden, Switzerland and the United States.
1. Business Expenditure on R&D (BERD) is the measure of intramural R&D expenditures within the business enterprise sector (regardless the sources of R&D funds).
Source: OECD (2018b), National Accounts (database), [Value added and its components by activity, ISIC rev4], Research and Development Statistics (database), [Business enterprise R-D expenditure by industry (ISIC rev4)]; MSTI Main Science and Technology Indicators (database), [BERD as a percentage of GDP], https://stats.oecd.org/.

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Policy incentives to private investment in R&D and innovation

In most reviewed countries, governments encourage innovation activities in the private sector, including by fostering knowledge markets through protecting intellectual property rights (IPRs), providing direct or indirect financial incentives, engaging in public-private partnerships (PPP), and providing information and sharing the outcomes of public research (spill-overs).

Intellectual Property Rights

IPRs provide an important incentive to invest in innovation by enabling firms to recover their investment. Rights-holders can exclude competitors from use of an innovation for a limited period of time or, in the case of open innovation approaches, they can promote access and sharing. The challenge for IPR regulations is to provide incentives for private investment in innovation, without compromising the sharing of knowledge and further innovation (OECD, 2013).

In most reviewed countries, there are two main types of IPRs used in agriculture: patents and plant variety protection in the form of a breeder's right. Duration of patent protection is generally 20 years. To facilitate the innovation process, Australia grants innovation patents with a shorter protection of eight years. The International Union for the Protection of New Varieties of Plants (UPOV) offers protection to the "breeder" of a plant variety, in

the form of a "breeder's right". This gives the developer of a new variety the right to exclude others from commercialisation, but allows farmers to use the seeds produced from a protected variety for subsequent plantings, and researchers to use them for further breeding research. The breeder's right under UPOV is granted for a period of not less than 20 years or, in the case of trees and vines, for not less than 25 years. In Estonia and Sweden, the duration of the right is longer (25 years and 30 years for trees). Argentina, Brazil, China, and Colombia signed the 1978 UPOV convention in the 1990s, but have not signed the 1991 one, which offers strengthened protection and improves the plant breeders' ability to recover their development costs and to generate funds for re-investment. Most other countries have signed the 1991 UPOV convention around 2000, but Turkey and Switzerland signed in 2007-08 and Canada in 2015 after the publication of the OECD review.

Some reviews also mention the importance of trade secrets, which give indefinite protection, in the development of hybrid seeds (OECD, 2016) or the protection of food and drinks. Several reviews also mention geographical indications, which also provide perpetual protection, but without commenting on their impact on innovation.

According to the World Economic Forum (WEF) Global Competitiveness Indicator, intellectual property protection is high in most of the reviewed OECD countries, which are knowledge-based economies (Figure 5.3). Most of the increase took place in the 1980s and 1990s, Plant Variety Protection has also increased significantly around 2000 with the signature of the 1991 UPOV convention. In the non-OECD member countries that were reviewed, patent protection is lower, but has increased significantly in the last decade.

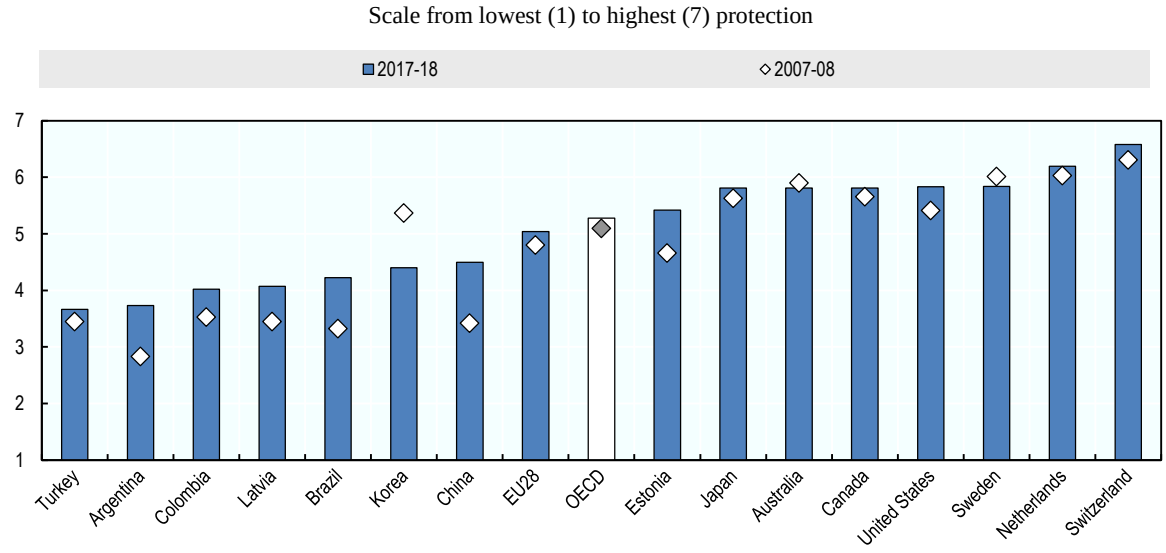
The strengthening of IPR protection in recent decades has been associated with an increase in private sector investment in agriculture-related research and development and a surge in innovation leading to improved plant varieties, agricultural chemicals, and production technologies. It has also provided farmers access to foreign innovations. Conversely, in Canada, delaying the adoption of UPOV91 (to 2015) compared to trading partners has limited Canadian farmers' access to new, more productive varieties: it limited levels of investment in the domestic plant breeding programmes of some crops, and many foreign breeders did not seek Plant Breeder's Right protection nor introduced their varieties into Canada.

Many reviews outline the significant impact of genetic improvement in agricultural productivity growth and the reinforcement of IPR protection in this development. Patent positions in combination with technological developments have led to large consolidation among breeding companies. The access barrier for new companies to the plant breeding sector is high, where IPR plays a role next to the large amount of knowledge and expertise required to set up a breeding company and the long development period for new varieties. New gene editing technics, however, become more accessible to smaller companies and shorten the process for developing new varieties. But in the absence of some breeding exemption under patent law entailing that anyone may make use of patented biological material for the purpose of breeding, or discovering and developing of other plant varieties without the consent of the patent holder, large breeding companies holding existing IPRs are likely to remain ahead (OECD, 2015b).

As noted in the Dutch review, however, not all innovations are or can be protected by IPRs, in particular non-technological innovations or in areas where fast adoption is required to maintain a competitive hedge, like horticulture (OECD, 2015b).

Most reviewed countries are members of the OECD Schemes for the Varietal Certification of Seed Moving in International Trade, which promotes the use of agriculture seed of consistently high quality, for most crops. Exceptions are China, Colombia and Korea. The OECD certification provides for official recognition of "quality-guaranteed" seed, thus facilitating international trade and contributing to the removal of technical trade barriers.[6]

Figure 5.3. Global Competitiveness Index: Intellectual property protection, 2007-08 and 2017-18



Note: Indices for EU28 and OECD are the simple average of member-country indices.
Source: World Economic Forum (2017), The Global Competitiveness Report 2017-2018: Full data Edition, http://reports.weforum.org/global-competitiveness-index-2017-2018/.

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Support to R&D investment

Mechanisms supporting private R&D investment are generally economy-wide and not specific to agriculture or food related activities. There is little information in country reviews on the extent to which this support benefits agri-food companies.[7]

Many countries increasingly support R&D through tax instruments (Figure 5.4). They include tax rebates on eligible income, profit, investment, exploitation costs, including cost of labour employed in R&D, or benefits from research projects, patents and royalties (e.g. Innovation Box in the Netherlands). The share of tax incentives in R&D support has been increasing in recent years. In some countries like Canada, most support to R&D is through tax incentives, while it is hardly or not at all used in others such as Estonia and Sweden.

The extent to which tax subsidies encourage additional R&D activities and reach intended beneficiaries, e.g. small and medium-sized enterprises (SMEs), which would not carry out R&D otherwise, needs to be investigated. They tend to favour companies, which make profit or have the capacity to carry out R&D activities, while the food and agriculture sector includes a high number of smaller companies with little capacity for research. Direct support gives more scope for targeting them.

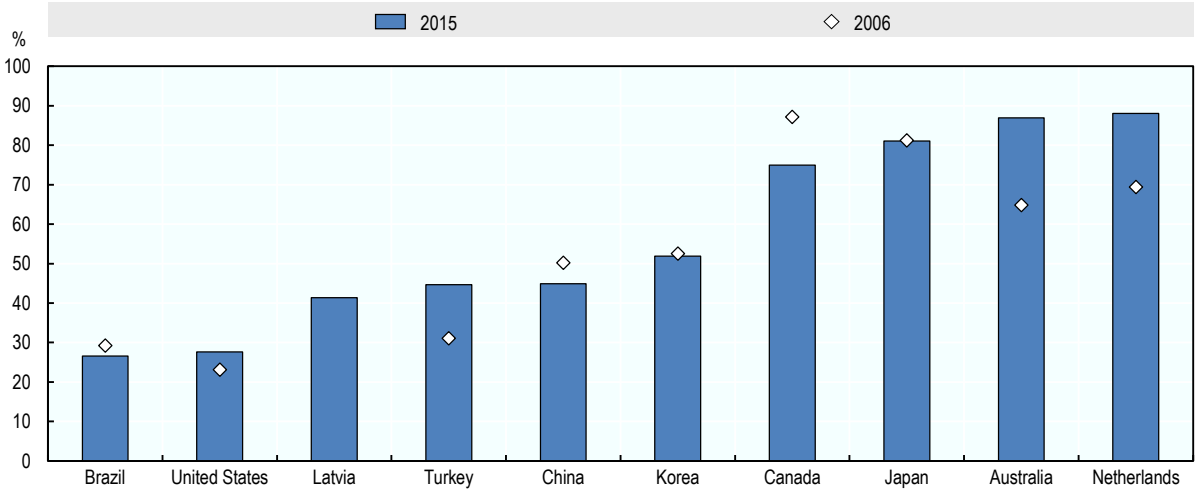
Most countries provide direct support to R&D investment in private companies, including through project funding and procurement mechanisms. Few mechanisms supporting innovation in private companies are sector-specific. In many countries, some target innovation in SMEs (e.g. the Small Business Innovation Research (SBIR) programme in the Netherlands and the United States), but the extent to which this support benefits the food industry is unclear. General mechanisms may include specific support earmarked for food and agriculture-related innovation activities, sometimes as part of a strategy (e.g. bioeconomy, genomics).

In some countries, agricultural policy includes support for participation in innovation partnerships or networks, as in the EU Rural Development Programme. In Canada, two programmes within AgriInnovation are geared towards encouraging industry-led innovation and investment: Agri-Science Cluster and Agri-Science Projects (Box 5.1).[8]

Demand-driven mechanisms are an innovative and promising way to fund research. Reviews mention the use of procurement or pull-mechanisms[9] for innovation in general, and some more specifically in food and agriculture. In the Netherlands for example, among the diverse business innovation funding instruments, two deliver project funding for public procurement addressing societal challenges (Table 7.4 in OECD, 2015b). Latvia developed regulations to facilitate green procurement, which should reduce the environmental impact of procured goods, and foster the development of environmentally-friendly goods and services. However, experience in the food and agricultural sector remains limited.

Figure 5.4. Change in government support for business R&D through direct funding and tax incentives, 2006 and 2015

Tax incentive as a share of government support for R&D



Note: There are no tax incentives for R&D in Estonia and Sweden, while in Latvia, they were introduced in 2014.
Source: OECD (2017), *R&D Tax Incentive Indicators*, https://oe.cd/rdtax (accessed July 2017).

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Public-private co-operation for innovation

Co-operation between various public and private actors in the agricultural innovation system is essential to increase the returns from public funds and to tailor innovations to needs. Public-Private Partnerships (PPPs) are one policy option, which may facilitate

improved outcomes but governance, design and implementation issues need to be carefully considered to ensure success (Box 5.2).

Reviewed countries use different institutional and funding mechanisms — public funding to research projects requiring public and private participation and co-funding, foundations, institutions. Table 5.2 provides examples of mechanisms to foster PPPs in reviewed countries. Most of them are not sector-specific, but apply to food and agriculture R&D. There are few examples of agricultural-specific mechanisms.

Box 5.2. Governance and implementation considerations for successful Public-Private Partnerships (PPPs)

- Setting clear objectives and rules, and implementing regular monitoring and evaluation is essential.
- Evaluation procedures need to be well-tested and include impact analysis.
- Transparency, consultation with stakeholders and the establishment of dispute settlement and exit strategies are also important.
- Institutional arrangements need to be clear, including the sharing of costs and benefits, particularly the terms governing the sharing of Intellectual Property Rights (IPRs) between partners.
- Once government has determined its priority areas, PPPs should be selected using a transparent, open and competitive process. Value for money is the main criteria but common aims, mutual benefits and complementarity among the partners are also important.
- Improving the capacity of partners is an important factor of success, and is particularly relevant for agricultural innovation. Providing specific education, training and advice to improve skills for PPPs management would help in this regard.

Source: Moreddu (2016), "Public-Private Partnerships for Agricultural Innovation: Lessons From Recent Experiences", https://doi.org/10.1787/5jm55j9p9rmx-en.

There is evidence that the number of PPP agreements is increasing in Brazil and the United States. The Agricultural Research Service (ARS) of the US Department of Agriculture (USDA) is engaged in R&D partnerships to address major challenges such as climate change, bioenergy, food security, pests, and water use. Moreover, an agriculture-specific institution, the Foundation for Food and Agricultural Research (FFAR), was created in 2014, as an independent, board-driven, non-profit organisation, to foster collaboration between government, university, industry, and non-profit researchers (Toole, 2014). PPPs are based on Cooperative Research and Development Agreements (CRADA). A CRADA is a written agreement between a private company and a government agency to work together on a R&D project, which allows both parties to keep research results confidential for up to five years under the Freedom of Information Act. It allows the government and the partner to share patents and patent licenses and permits one partner to retain exclusive rights to a patent or patent license. In 2016, the Ministry of agriculture, forestry and fisheries of Japan launched the Council of Industry-Academia-Government Collaboration for "The Field for Knowledge Integration and Innovation (FKII)", which aims to be a cross-sectoral platform of people, information and funds for agricultural research (Box 5.3).

Table 5.2. Public-Private Partnership programmes for R&D, selected countries

	Name	Duration	Responsibility	Description
Australia	Co-operative research Centres (CRCs)	Since 1990	Industry	Partnerships between different research funders, suppliers and end users formed to undertake R&D in specific areas, with a particular emphasis on applied R&D
	Research and Development Corporation (RDC)		Rural	Industry (farmers)-public co-finance and have a say in what research is done but farmers do not conduct research
Brazil	Legal Framework and funding mechanisms	2004	Research	Facilitate the participation of public entities in co-operation activities, and sharing of equipment
Canada	Network of Centres of Excellence (NCE)	Since 1989	Science-research	NCEs help mobilise multi-disciplinary research capacity, create large-scale, academic-led research networks, and engage public and private partners
	AgriInnovation	Since 2013	Food and agriculture	As part of the Industry-led Research and Development stream, agri-Science Cluster support aims to mobilise and co-ordinate a critical mass of scientific expertise in industry, academia and government (Box 4.1)
Estonia	Competence Centre (CC) programme	Since 2004	Enterprise Estonia	Competence centre: private entities established by a consortium of R&D institutions and enterprises (Box 7.3 in OECD, 2018c). Three out of six CC concern the food and agricultural sector[1]
	Innovation and development vouchers	Since 2008	Enterprise Estonia	Provides SMEs with grants for co-operating with higher education institutes, test laboratories or Intellectual Property experts to develop innovative solutions
	Cluster programme	Since 2008	Enterprise Estonia	No agricultural enterprises were eligible
European Union	RDP measure co-operation	Since 2014	Agriculture	EU Member States can choose to provide funds to R&D co-operation projects
Japan	Field for Knowledge Integration and Innovation	Since 2016	Agriculture	A cross-sectoral platform of people, information and funds in agricultural research (Box 5.3)
Netherlands	Top-Sector policy	Since 2011		Box 5.4
Sweden	VINN excellence Centre	2003-18	Industry-Energy-Innovation	Competence centre
United States	Engineering research centres	Since 1985	Science	Competence Centre
	Industry-University Co-operative Research Centre	Since 1979	Science	Competence Centre
	Small Business Innovation Research (SBIR) programme		Small Business Administration	Funding programme for small business to engage in Federal R&D – with potential for commercialisation
	Small Business Technology Transfer (STTR)		Small Business Administration	Funding programme to facilitate co-operative R&D between small business concerns and US research institutions – with potential for commercialisation
	Foundation for Food and Agricultural Research (FFAR)		Agriculture	Independent, board-driven, non-profit organisation created to foster collaboration between government, university, industry, and non-profit researchers. Funding is distributable only with an equal amount of non-Federal matching funds

Note: 1. There is also a regional CC and a Centre of Excellence with activities related to plants.
Source: Moreddu (2016), "Public-Private Partnerships for Agricultural Innovation: Lessons from Recent Experiences", https://dx.doi.org/10.1787/5jm55j9p9rmx-en.

Box 5.3. Platform for open innovation in agriculture in Japan

In 2016, The Ministry of agriculture, forestry and fisheries of Japan launched the Council of Industry-Academia-Government Collaboration for "The Field for Knowledge Integration and Innovation (FKII)". FKII aims to be a cross-sectoral platform of people, information and funds for agricultural research. The FKII is composed of three-layers:

- The Council of Industry-Academia-Government Collaboration that exchanges information among members such as producers, private companies, universities, research organizations.
- A R&D Platform that engages in collaborative research led by a designated research director.
- A Research Consortium that perform joint research.

As of May 2018, FKII includes 1 751 organisations and 690 individual members in the council, and launched 118 R&D platforms.

Cross-sectoral collaboration through FKII is expected to promote the commercialisation of new technology and enhance incentives for private investment in agricultural R&D. Most of the private companies engaged in R&D related only to the merchandising or commercialisation of their own products or services. Universities and public research organisations have been playing a central role in basic and applied research, which requires a long time horizon before results are commercialised.

FKII is intended to connect each R&D stages with the participation of diverse actors of the Agricultural Innovation System. The financial support through FKII focuses on the commercialisation of research output from basic to applied, in a three-to five-year period.

NARO Bio-oriented Technology Research Advancement Institution (BRAIN) provides support for R&D that adopts a new support mechanism via a matching fund method designed to encourage collaboration with private-sector companies, as a model R&D project that uses new open innovations conducted in the FKII. A total of 17 agricultural, forestry and fisheries projects were adopted in the model projects that were offered from public proposals in 2016/17. They include, for example, "development of a model plant factory system for the Asian monsoon region" and "development of an AI robot-operated greenhouse."

Source: MAFF (2016), Field for Knowledge Integration and Innovation: Organization and Evolution Since Fiscal Year 2016, www.knowledge.maff.go.jp/uploads/0f46f5c7b37748f264f227c4073ffd134b453ba3.pdf.

The Netherlands went the furthest in placing PPPs at the heart of the R&D strategy introduced in 2011 — the Top Sector policy (Box 5.4). Nine key sectors have been identified with strong market positions. Two Top Sectors are dedicated respectively to the export orientated agri-food sector, and the horticulture and propagation materials sector. The aims are to maintain the competitive edge of these sectors, through innovation; increase private investment in pre-competitive research and foster networking. However, by giving the industry a leading role in setting innovation agendas, this policy risks focusing public funds on low risk and short-term R&D activities, away from research with more fundamental, public goods aspects needed to address long-term challenges. As originally implemented, the policy raised concerns over the long-term capacity of the agricultural innovation system. It also appears that while cost sharing is 50-50 in the agriculture-related top sectors, the effective private contribution is smaller when investment support and tax rebates are taken into account (OECD, 2015b).

Box 5.4. The Top Sector policy in the Netherlands

Implementation

The Top Sector policy subjects the granting of public funding to participation in PPPs within top sectors and gives industry a leading role in setting innovation agendas. Public funds have to be matched with an equivalent contribution from the private sector (50-50), which can be in kind (access to facilities) or financial, in which case it can benefit from public support (investment or tax rebates).

In the Top Sector policy the business community sets together with the government and scientists the agenda for R&D investments in its field. The government invites businesses and scientists to draw up action plans, which serve as a base to develop concrete lines of actions.

Each top sector has created one or more Top Consortia (TKI) for knowledge and innovation, where entrepreneurs and researchers work together in innovative products and concepts. Every TKI has a board with members from business and knowledge institutes. The government is an observer in the board. Programming is done by calls to tender leading to a number of identifiable projects since 2012. The activities of top sectors are regularly monitored through TKI's reports.

The basis for the implementation of innovation activities is the Innovation Contract. Each Top Sector draws up an Innovation Contract, in which researchers, entrepreneurs and the governments (represented in the so-called Top Team) agree on measures (mix of fundamental research, applied research, valorisation), plans to develop innovative products and services, and financial contributions.

Initial findings

One original objective of the Top Sector Policy was to leverage business-sector R&D and increase the applicability of public research. While companies participating in top sectors already invested in innovation, public co-funding focussing on pre-competitive research was expected to reinforce their contribution in this area. Early findings suggest companies, including multinational ones, increased investment in pre-competitive research, but that total private expenditures did not increase overall.

The policy was also expected to promote closer co-operation between knowledge institutes, public authorities and business. In the food industry, they improved co-operation between the processing and retail levels, as co-operation already existed among other components of the chain. All top sectors have a human capital agenda meant to strengthen the linkages between education institutes (from vocational training to university) in order to meet the needs of the sector itself.

The PPP approach is also to facilitate the marketing and adoption of innovation, and reduce the technological gap between small and large companies through knowledge transfer, as quality systems become more complex.

Source: OECD (2015b), *Innovation, Agricultural Productivity and Sustainability in the Netherlands*, https://dx.doi.org/10.1787/9789264238473-en.

Overall, support to private R&D and PPPs often benefits multinational companies to a greater extent than smaller enterprises as they have a greater research capacity. Some programmes, however, target specifically smaller companies.

In a few countries, farmers contribute to the funding of agricultural R&D via statutory or voluntary levies. Some processors also pay levies (red meat processors, timber mill operators, sugar mills, and winemakers). Levy funding ensures that research is adapted to industry needs and thus widely adopted, but favours major, well-organised commodity sectors. The Australian Research and Development Corporation (RDC) model, based on

50-50 co-funding by farmers and the government, channels a large part of agricultural R&D funding (Box 5.5). In some RDCs, the industry levies exceed the matching cap. While organised by commodity sectors, some RDCs have wide coverage, including small and emerging industries (OECD, 2015c). In Canada, mandatory levies (check-off) are used to financially support both marketing and research activities for a variety of farm products. A majority of check-off systems is implemented and managed at the provincial level. In Colombia, research activities conducted by producer associations are funded through commodity taxes levied on private sector production or exports. Thirteen producer associations are involved in agricultural research. Some producer associations have their own research facilities, called "supply chain research centres" (CENIs), and conduct their own research (OECD, 2015d). The four main research centres are for coffee, palm oil, sugar cane and rice. In Sweden, the Federation of Swedish Farmers (LRF) created in 1996 the Swedish Farmers' Foundation for Agricultural Research as an independent legal organisation receiving funding from both the LRF and the government. About SEK 57 million are distributed every year in support of agricultural needs-driven research, of which about two-thirds from private sources. In total the Foundation budget is equivalent to around 13% of total government funding on agricultural R&D (OECD, 2018d).

Box 5.5. The Australian rural Research and Development Corporation (RDC) model

A unique feature of the Australian rural innovation system is the Rural Research and Development Corporation (RDC) model of co-financing of rural R&D activities established in 1989. It places interactions between public R&D and agricultural industries at the heart of the rural innovation system and has channelled in recent years a significant share of Australian Government spending on rural research and development (R&D).

Under the RDC model, the Australian Government matches industry R&D funds collected from primary producers via statutory or voluntary levies, dollar for dollar, with maximum matching contribution per year of 0.5% of an industry's gross value of production.

This co-investment model:

- Generates greater spending capacity.
- Ensures that producers who benefit from research contribute to its costs.
- Ensures that research is of practical value.
- Facilitates greater and faster uptake of research outputs.

R&D activities within RDCs involve various rural and general R&D institutions and are organised by commodity, although some RDCs address broader challenges at supply-chain level. Originally competitive- and market-driven, the model has become more collaborative and inclusive. While the RDC model does not directly integrate agribusiness processing and retailing stakeholders in funding decisions, potentially limiting capacity to respond to demand for product and process development along the food chain, many RDCs undertake extensive marketing aspects including trade access and working along the supply chain to determine product and process development needs. By design, the RDC model is more adapted to marginal improvements than fundamental changes in production systems and resource management. Past evaluations have questioned the complex arrangements and unclear funding flows making evaluation difficult. They have also found that the overall level of public support for industry-focused research too high, outlining that the basis for the Government's matching contribution to RDCs provides no incentive for producers to increase their investments in the model over time (Productivity Commission, 2011).

Source: OECD (2015c), *Innovation, Agricultural Productivity and Sustainability in Australia*, https://dx.doi.org/10.1787/9789264238367-en, based on Productivity Commission (2011), Rural Research and Development Corporations, Report No. 52, www.pc.gov.au/projects/inquiry/rural-research.

Farm advisory systems

Farm advisory systems have had an important role in the transfer and successful adoption of innovation, in particular at early stages of development. There is a wide diversity of systems, public and private providers and funding mechanisms within and across reviewed countries (Table 5.3).

The role of the government varies from being the main funder and provider like in Japan and Korea, to co-funding and guiding services managed by independent organisations like in Estonia. In some countries, farmers' organisations play an important role in providing advice to farmers, who pay collectively or individually for services. In the Netherlands, the national advisory system was privatised and replaced by a diversity of private providers. Consulting firms emerged also in different countries, in particular for specialised knowledge such as management or Information and Communication Technologies (ICTs). Small amounts of subsidies are available in the Rural Development Plan (RDP) for farmers to access services. In Brazil, public provision is only for smaller farms, while large commercial farms are expected to pay for the service.

Table 5.3. Examples of advisory services

	Main institutions	Source of funds	Countries
State-run	Public organisations at regional and national level	Wholly financed from public funds	Brazil for smaller farms, Colombia, Japan, Korea, Sweden, Turkey, United States
Public-Private Service	Increasingly provided by private consultant firms	Farmers partly or wholly pay for services; centralised and decentralised	Canada, China, Estonia, Australia, United States
Farmers' Organisations	Farmers' organisations	Membership fees and payments by farmers	Australia, Canada, Colombia, Japan, United States
Commercial	Commercial firms or private individuals	Payment through project implementation or grants	Netherlands, commercial farms in Brazil, Turkey, United States

Note: Several systems co-exist in some countries.
Source: Adapted from OECD (2013), *Agricultural Innovation Systems: A Framework for Analysing the Role of the Government*, https://dx.doi.org/10.1787/9789264200593-en; and OECD (2015e), *Fostering Green Growth in Agriculture: The Role of Training, Advisory Services and Extension Initiatives*, https://dx.doi.org/10.1787/9789264232198-en.

In addition to established advisory services, farmers receive advice from input suppliers, downstream industries (in particular with integrators, labels, organic) and co-operatives.

Farm advisory services are in transition to meet new demands without increasing costs. A few trends can be observed:

- Farm advisory services need to cover a broader range of subjects and respond to wider and more complex issues. Beside technological innovation to increase productivity growth and competitiveness, farmers increasingly need advice to implement more sustainable practices, better manage their farm, and market their products. Advice needed is thus less commodity specific, more focused on production systems and environmental issues.
- Specific mechanisms are developed to facilitate compliance with regulations or policy requirements. For example, the EU Farm Advisory System was originally meant to help with cross-compliance conditions; US conservation policies include funding for technical advice on how to comply.

- As a result of efforts to reduce costs and increase coverage, public systems increasingly provide advice to groups of farmers, while farmers are expected to pay for individual advice. This often goes along with a reduction in the number of advisors as mentioned in the Australian and Estonian reviews.
- ICTs are increasingly used to transfer knowledge and information, thus allowing for better inclusion of remote farmers.
- It is difficult to interpret changes in public funding over time, as it may reflect the growing importance of a healthy private sector or a decrease in access.
- New intermediary, private actors have emerged following the privatisation of government services (in the Netherlands), or the introduction of competition (in Turkey), but also to help with new technologies. For example, more efficient and cheaper digital technologies have prompted the creation of knowledge intermediaries to help farmers benefit from digital services).
- Some countries focus public provision on public good aspects, e.g. poor farmers (for example in Brazil and Colombia), and policy and environmental aspects (for example in Estonia and the United States).
- Some countries pay farmers to access advisory services, rather than subsidise the service itself.
- Some countries try to reach out farmers who do not use advisory services, e.g. in Brazil and Colombia.
- The main role for the government is in the governance of the system to ensure provision is adequate, and all farmers have access to a competitive supply of advisory services, covering both productivity and sustainability aspects, and type of advice (technology, management, policy or marketing). Governments should in particular:
  - Set qualitative and quantitative objectives, and guide the evaluation of performance.
  - Ensure extension officers are well-trained (certification) and keep informed about the most recent knowledge via re-training or participation in innovation networks.
  - Facilitate networking and exchanges of knowledge between advisors and with other actors.
  - Facilitate the use of most advanced technologies to communicate.
  - Focus public funding on public good aspects through supporting services or farmers access to services.
  - Explore innovative ways to reach farmers who are out of the system, for example by making participation a condition for receiving support.

Farm advisory systems are very different across countries and often include many public and private providers, enabling farmers to choose. However, this makes it difficult to share experience and allow evaluation. Few countries mention evaluating advisory services, although the evaluation of government spending may follow the framework of general policy evaluation in some countries. For example, policy evaluation in Estonia led the government to target public services to farmers with lack of access to private ones.

Moreover, *ad hoc* research studies have addressed the effectiveness of advisory systems, in particular in emerging economies. A general conclusion is that further analysis is needed to better understand farmers' needs and main barriers to adoption.

Given enabling market and policy incentives, other mechanisms to facilitate innovation in food and agriculture, include participation in networks, co-funding in public-private projects, investment support in farms and firms.

International research co-operation

International co-operation on agricultural research and development offers universal benefits. While this is generally true given the public good nature of many innovations in agriculture, it is particularly the case with global challenges — as in the case of responding to climate change — and when initial investments are exceptionally high. The benefits of international co-operation for national systems stem from the specialisation it allows and from international spill-overs. In countries with limited research capacity, scarce resources could then focus on better taking into account local specificities.

The importance of bilateral and multilateral co-operation in R&D and technology transfer is well recognised and various mechanisms, which are not necessarily agriculture-specific, facilitate this co-operation. They include exchange of students and staff, which are encouraged in many countries (e.g. Canada); and co-financing of and participation in international projects, initiatives and networks. Brazil developed an interesting exchange mechanism to facilitate international collaboration (Box 5.6).

Box 5.6. The Brazilian Virtual Laboratories Programme (Labex)

Embrapa in Brazil created Labex (Virtual Laboratories Programme) to promote opportunities for institutional co-operation in agricultural research and to monitor scientific advances, trends, and activities of interest to agribusiness in partner countries. Embrapa selects and sends senior researchers to develop strategic research for Brazil in partnership with R&D centres of excellence in agricultural research. Since 1998, Embrapa has opened virtual laboratories in the United States, Europe (France, England, the Netherlands and Germany), Korea, China and Japan.

The programme also provides for the reverse route: at the so-called “reverse Labex”, researchers from partner international institutions are established in Embrapa's research centres to develop projects of mutual interest.

Source: OECD (2015f), update in www.embrapa.br/en/web/portal/embrapa-labex.

An important part of international collaboration for agricultural R&D concerns agricultural development, for example in the CGIAR system (www.cgiar.org/), or the Global Forum on Agricultural Research (GFAR – www.egfar.org). In this area, international efforts also aim to develop capacity for agricultural innovation in developing countries.[10]

Reviewed countries also participate in a number of international initiatives focusing on global challenges, in particular climate change.[11] These include G20 initiatives for collaboration on agricultural research, for example the Wheat Research Initiative (IRIWI – www.wheatinitiative.org); the Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM – www.geoglam.org/index.php/en/).

EU innovation policy aims to bring together researchers from different EU Member States. The Standing Committee on Agricultural Research (SCAR) plays a major role in the

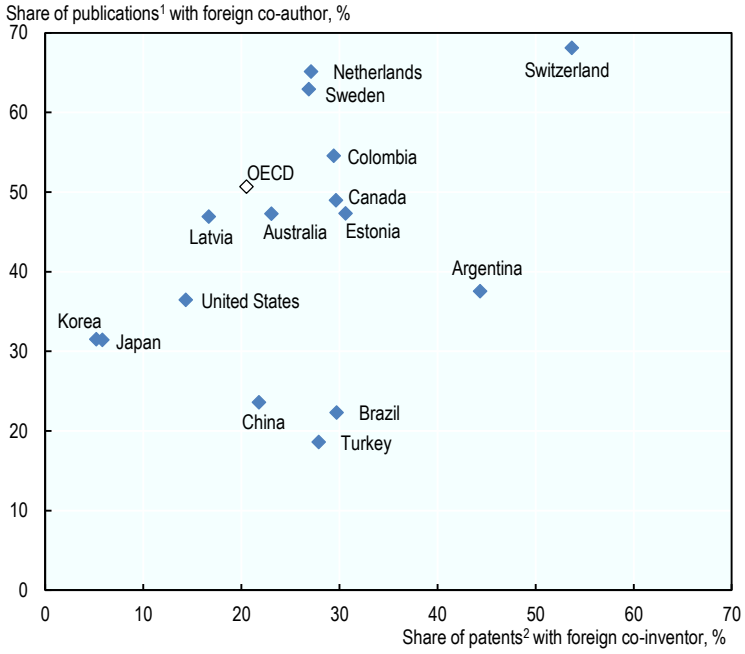
co-ordination of agricultural research efforts across the European Research Area (ERA), including by establishing Collaborative and Strategic Working Groups to define common priorities. As part of the ERA, successive EU Framework Programmes and current Horizon 2020 fund multi-country teams, selecting projects on a competitive basis. In addition, different initiatives also facilitate cross-country collaboration. They include ERA-nets, Joint Programming Initiatives (JPIs) and more recently European Innovation Partnerships (EIPs). The reviewed EU Member States participate jn various ERA-nets (e.g. on pest and disease research), in the JPI on Agriculture, Food Security and Climate Change (FACCE), and the EIP on Agricultural Productivity and Sustainability. Moreover, fostering international co-operation in research and innovation is a strategic priority for the European Union, and participation of researchers from third countries in EU-funded projects and initiatives has gradually increased over time.

In most countries, the share of scientific publications on agro-food research including at least a foreign co-author is above 30%, and reaches levels above 60% in the Netherlands, Sweden and Switzerland, reflecting both high research capacity and focus on collaborative work, in particular at the EU level (Figure 5.5). The share of patents with foreign co-inventors is the highest Switzerland (54%) and Argentina (45%), and is between 20% and 30% in a majority of reviewed countries. The relatively modest share of outputs from co-operation with foreign researchers in the United States reflects the large share of national R&D by international standards, rather than the small level of co-operation with other countries.

Few country reviews mention significant obstacle to international co-operation, although the mandate to focus on national issues may limit the scope for it. There are also concerns in some countries that restrictions on immigration may limit exchanges of researchers and students, identified as an efficient mechanism to facilitate cross-country co-operation.

Figure 5.5. International co-operation in agro-food R&D, 2007-12

Agro-food outputs with foreign partners as a share of total agro-food outputs



Notes: 1. Publications in scientific journals. OECD average excludes Lithuania. Data refer to agro-food outputs for 2007-12.
2. Patents filed under the Patent Co-operation Treaty (PCT). Data refer to agri-food outputs for 2006-11.
Source: OECD (2014), *OECD Patent Database* https://stats.oecd.org/ (accessed February 2014); SCImago. (2007), SJR — SCImago Journal & Country Rank, www.scimagojr.com (accessed 19 March 2014).

StatLink https://doi.org/10.1787/888933998747

Summary of innovation policy indicators

Table 5.4 recapitulates key indicators that characterise Agricultural Innovation Systems and innovation policy approaches in reviewed countries.

Table 5.4. Summary of the main characteristics of Agricultural Innovation Systems and innovation policy approaches

	Governance: Evaluation practices	Agricultural research intensity	Food industry research intensity	IPR	R&D steering	Research outputs		Research output with foreign co-author		Extension system
	1: ad hoc; 2: project and staff 3: 2+ institution level 4. 2+wrt policy objectives 5: 3+4 6: 3+4+RoI 7: 6+ other IA	Public expenditure on agricultural R&D as a % of agricultural GVA[1]	Food industry expenditure on R&D as a % of Food manufacturing GVA[2]	1 to 7 (highest)	Share of project-based funding in total funding for agricultural R&D: 1: 0-20%; 2: 20-40%; 3: 40-60%; 4: 60-80%; 5: 80-100%	Number of agro-food patents relative to the sector's GVA (USD billion)	Number of agro-food publications relative to the sector's GVA (USD billion)	As a % of all agri-food patents	As a % of all agro-food publications	1. Diverse and interactive; 2. Strong public extension services; 3. Strong role of farmer organisations; 4. Dual-unequal
Argentina	1 and 3	0.6	..	3.6	1			44.3	37.5	4
Australia	7	1.5	..	5.8	3			23.1	47.3	1
Brazil	3 and 6	1.8	..	4.1	1	0.4	50	29.7	22.3	4
Canada	4	1.9	0.5	5.9	2	4.0	157	29.7	48.9	1
China	..	0.6	..	4.3	1			21.8	23.6	2
Colombia	4	0.8	..	4.2	4			29.4	54.5	4
Estonia	4	1.4	0.8	5.5	4	3.8	170	30.6	47.3	2
Japan	4	1.8	1.7	5.9	1	7.0	51	5.2	31.5	2
Korea	4	3.0	2.7	4.4	1	6.9	60	5.8	31.4	2
Latvia	4	..	0.2	4.2	2	0.3	24	16.7	46.9	3
Netherlands	5	0.9	2.7	6.2	5	11.7	112	27.1	65.1	1
Sweden	3	0.9	1.0	6.1	3	11.2	223	26.9	62.9	1
Switzerland	2	2.2	0.5	6.5		15.6	196	53.7	68.1	
Turkey	2	0.2	0.2	3.7	2			27.9	18.6	2
United States	7	1.4	2.7	5.9	4	8.8	94	14.3	36.4	2

Notes: ..: Not available; GVA: Gross Value Added; 1. GBARD; 2. Business Expenditure on R&D (BERD) is the measure of intramural R&D expenditures within the business enterprise sector (regardless the sources of R&D funds).

Main knowledge gaps

Country reviews generally contain a good description of the agricultural innovation actors and funders, and the governance structure. It is however difficult to assess the functioning of the mechanisms to set priorities, co-ordinate with other policies and sectors, consult stakeholders. The nature and scope of evaluation procedures are also difficult to assess.

Overall, information needed to monitor and evaluate R&D and innovation in food and agriculture, and to assess the performance of Agricultural Innovation Systems is not sufficient.

The most surprising finding is the difficulty to track funding of agricultural R&D over time and across countries. Despite the existence of international standards for reporting R&D expenditure, reporting at sector level is often incomplete in the OECD database. The OECD database includes different indicators of expenditures on R&D, mainly GBARD, Government Expenditure on R&D (GERD) and BERD, and its components. If coverage is quite good at the national level, there are multiple gaps and discrepancies at the sector level. GBARD for agriculture is the most widely available and most timely as it originates from budget sources, but it only captures public expenditures budgeted for agriculture. However, some countries increasingly use general funding mechanisms to finance agricultural research. GERD and BERD come from surveys and the time series are sometimes incomplete or dated.

GERD for agricultural sciences is mostly available for two sectors of performance: government and higher education, and includes both public and private funding of research performed in these sectors. Public and private funding of R&D for agricultural sciences in the private sector is often missing. Moreover important countries like the United States do not report any data according to this classification. Series for GERD by sector of performance for agriculture as an economic objectives are shorter and mainly incomplete. GERD by funder is not available.

Information on private funding of research on food and agriculture is incomplete and often lacking in smaller countries and for smaller companies. In most countries, the diversity of research funding channels, and of research organisations makes it difficult to track public funding to its end-use. As a result, the OECD database does not allow tracing sources of funding to sectors of performance like in Figure 7.4 of the US review (OECD, 2016c). BERD in food processing companies has good coverage but not BERD for agriculture.

Quantitative information on funding mechanisms is not available in all countries, and assumptions had to be made to fill the fifth column in Table 5.4. Similarly, there is little information on the distribution of funding by level of research from fundamental to applied, by commodity sector or by issue.

As part of innovation policy, governments support R&D and innovation, through various mechanisms and programmes. Some country reviews contain detailed information about these, but not much on whether agriculture and food companies benefit from them.

Few country reviews report on the results of national evaluation of agricultural innovation systems (Mainly Australia, the Netherlands and the United States). All reviews include indicators of research outputs (bibliometrics and patents) that come from international databases, but they do not necessarily cover all types of research activities. More efforts are needed to measure research outputs, but also to build more meaningful indicators for cross-country comparison. Country reviews include relative indicators of the share of agri-

food patents or publications in the national total, which indicate the relative specialisation of the research system, to compare to the share of the sector in the economy. They also include the country's contribution to world totals, which are particularly interesting for large countries. To evaluate research efficiency, research outputs would need to be related to some indicator of size or efforts, such as the number of researcher or the expenditure on agricultural research, but coverage often differ. Patent and publication numbers cover both public and private sector, as well as agriculture and food processing, while research effort covers mainly researchers and research expenditure in public organisations. To facilitate cross-country comparison of availability of research output for the sector, Table 5.4 presents the number of agro-food patents and publications relative to the sector's gross value added.

Evaluation of research impacts poses methodological challenges, in particular in terms of attribution, evaluation of longer term impacts and non-market impacts (Alston, 2010; Joly et al., 2016). Some countries are developing procedures and guideline, and efforts are made at international level in this area (OECD, FAO), but more concerted efforts are needed.

Except in ad hoc surveys, most countries have little information on farm-level adoption of innovation and use of advisory services. This makes it difficult to identify the factors that facilitate adoption and the impacts of adoption on farm performance. More information is available on firm-level innovation, as part of EU industry and innovation surveys, mainly for the food and drink processing industry. While the role of advisory systems in the adoption of innovation is recognised, there is little evidence available on the performance of specific extension systems and their ability to reach out the farmers most in need to improve their productivity and sustainability performance.

Recommendations to improve the agricultural innovation system

This section consolidates recommendations to strengthen agricultural innovation systems made in country reviews, which are included in the country notes of Annex B.

Improving governance of agricultural innovation systems is key

- Establish a longer-term strategy for agricultural innovation to guide operational objectives and associated expenditures, taking into account long-term challenges such as climate change, as well as societal demand.
  - Ensure coherence between innovation and growth strategies;
  - Improve the integration of agricultural innovation objectives in government-wide innovation strategy;
  - Improve involvement of stakeholders in the definition of objectives, starting at an early stage of the process; and
  - Include measurable targets in the definition of objectives; and monitor progress towards objectives.
- Improve co-ordination between research organisations, public and private and at the national and sub-national levels:
  - If missing, create a specific national institution (e.g. a national council) to co-ordinate objectives and monitor policy, and ensure continuity in programming.

  - Clarify mandates of organisations to avoid duplication or under-supply in one area (for example between research and knowledge transfer).

- Develop coherent evaluation procedures at different levels (researchers, projects, institutions, system) that include some independent evaluation and cover a wide range of indicators of efforts, outputs and impacts to allow for future improvements. Ensure evaluation criteria are consistent between levels and with objectives.

Strengthen linkages within the national innovation system to increase efficiency and responsiveness to needs

- Facilitate linkages within the agricultural innovation system (between research, advisory services, education, government, farmers and agri-food companies) and with other experts and stakeholders.
- Promote and enable research co-operation across sectors, so that food and agriculture benefit from advances in other sectors and generic research, such as genetics, digital technologies.
- Remove institutional constraints to public research organisations to engage in co-operation activities with the private sector.
- Facilitate the organisation of producers and industry to enable them to contribute more effectively to the agricultural innovation system.
- Facilitate the emergence Public-Private Partnerships (PPPs) for research and innovation, when they bring additional benefits. Provide guidelines for successful PPPs, and in particular, ensure objectives are shared, institutional arrangements are clear, including the sharing of costs and benefits between partners, which should be commensurate.
- Create and support poles of competitiveness, or poles of excellence to facilitate co-operation.
- Explore further opportunities to share public infrastructure with the private sector.
- Identify areas where local companies and researchers could collaborate to develop local or niche products and innovation.
- Support the functioning of local, national and international networks for innovation and the participation of researchers and stakeholders in these networks.
- Strengthen the links between R&D and technical assistance, for example by adding technology transfer component to research projects, or by encouraging networking between researchers, advisors and producers.

Simplify research programming to improve effectiveness and transparency

- Simplify the programming of R&D and innovation funding, and provide clear information to improve access. For example, streamline funding programmes and build a single platform that informs on all the sources of available government funding. When relevant, include information on sub-national sources.
- Review the efficiency of research funding mechanisms to ensure higher impact. Consider greater use of incentives that incentivise transdisciplinary and system-based approaches, and wider stakeholder involvement that increases relevance.

Explore ways to generate new (breaking through) ideas to overcome current constraints, for example through demand-driven funding mechanisms.

- Explore ways to generate new (breaking through) ideas to overcome current constraints, for example through demand-driven funding mechanisms.

Focus public funding of agricultural R&D in areas with public good aspects to improve complementarity with other efforts

- Provide stable funds for knowledge infrastructure, including knowledge technologies, institutions, networks and databanks, and long-term, large scope projects to maintain or strengthen the capacity of public research to meet public objectives and collaborate with private and international partners.
- Improve complementarity of public research funding:
  - with private efforts, by focusing public funding to areas that are not covered by, or complement, private efforts (including by agri-food companies and value-chain organisations), in particular areas with public goods aspects such as management of natural resource use, low carbon technology, and resilience to large-scale risks, and global food security.
  - at the national, sub-national and international levels. In EU Member States, improve consistency between EU and national rules and objectives to facilitate participation in EU programmes.
- Dedicated specific funds for policy-relevant research, i.e. research that generates information needed to improve policies.
- In country where research is organised by commodity sector, create cross-sector thematic areas and projects, including environment, or broaden the scope and membership of existing commodity research systems.
- Explore ways to generate new, break-through solutions to current and future challenges.

Strengthen private contribution to R&D and innovation for food and agriculture to increase impact

- Enhance the involvement of processing industries and retailers in innovation, by making them an integral part of the system, from the priority setting stage to the financing and commercialisation of innovation stages.
- Evaluate programmes that support innovation in private companies to ensure they are efficient and reach intended beneficiaries. In particular, monitor whether their reach agri-food companies. If private companies have access to tax incentives for R&D, evaluate the system to ensure it stimulates additional research activities.
- Strengthen and harness the capacity of private companies to participate in research partnerships via project funding, support to networking, training activities, and effective Intellectual Property Rights (IPR) protection.
  - Ensure appropriate protection of IPR, and improve enforcement when needed, to attract private funding, while allowing for further use for research purpose, as with Plant Breeders' Right.

- Explore alternative sources of funding for research and innovation:
  - This could include farmers' contributions, and revenues from royalties or Intellectual Property.
  - Investigate the demand and supply for venture capital for agri-food companies, and identify possible role for the government to ease constraints.
  - Lower barriers to FDI in agricultural R&D if they exist.

Facilitate international R&D co-operation

- Explore opportunities for public research to engage in bilateral, regional and multilateral co-operation in R&D and technology transfer
- Remove institutional constraints to public research organisations to hire foreign researchers of trainees
- Providing positive incentives such as support to student and staff exchange, sharing of equipment and laboratories.

Strengthen farm advisory systems to facilitate adoption

- There is no one size fits all or preferred model for farm advisory systems.
- Encourage a diverse supply of relevant advice from diverse public and private suppliers.
- But ensure needs are met:
  - Review current systems, and identify needs and gaps.
  - Ensure advisory services cover technical, financial and organisational aspects, and sustainability improvements.
  - And advice is accessible for all types of farmers, using new (digital) technologies.
- Focus public role on services that the private sector eventually under-provides:
  - Target the needs of small, semi-subsistence farmers to broaden their opportunities.
  - Strengthen environmental performance by providing targeted advice on sustainable technologies and practices, and use experience to better understand issues and needs.
- Explore the scope for including support to technical assistance and research projects within agri-environmental policies, in case of under-provision.
- Facilitate the sharing of experiences through networking, the development of databases.
- Ensure advisors have up-to date knowledge, possibly through certification, and facilitate continuous training.

Facilitate knowledge sharing and information dissemination

- Continue developing information systems to guide policies, research and innovation, and facilitate knowledge sharing.
  - Include market intelligence (big data) and research results.
  - Monitor innovation adoption in form and farm surveys, surveys to generate data on innovation and better understand motivations and barriers to adoption.
  - Monitor environmental performance in surveys.
  - Use innovative methods to reduce collection costs and improve farm and firm participation, drawing on experience from other countries.
  - Develop indicators and tools to evaluate the performance of the agricultural innovation systems in general, and innovation policy regularly, taking longer-term effects into account.
- Promote the integration of research data and sharing of experience at the international level.
- Improve public understanding of the importance of innovation in food and agriculture, in the sector and society, and build trust in science through increased transparency and education.

Notes

[1] TÜBITAK is the Scientific and Technological Research Council of Turkey. Its mandate is to guide, co-ordinate and fund national science, technology and innovation. It also performs research in strategic R&D areas, including agro-food research in the Food institute and the Genetic Engineering and Biotechnology Institute.

[2] Government budget allocations for R&D (GBARD) are more widely and timely available across countries than Government Expenditure on R&D (GERD). However, it provides only a partial indicator of investment in public agricultural research, since it refers to research funding instruments dedicated specifically to agriculture. In some countries, however, agricultural research funding comes through more general competitive funding programmes that are not captured in "agricultural" GBARD.

[3] Updating the database built used in Fuglie et al. (2011), Fuglie (2016) estimates that global private agricultural R&D spending tripled in nominal terms during 1990-2014, while private spending for food also tripled during 1990-2012. The database on global private agricultural R&D tracks agriculture-related R&D expenditure by major companies conducting research in this area, adding an allowance for R&D spending by small and mid-size firms. Companies are classified into seven farm input sectors. To allocate expenditures by countries, private R&D is assumed to take place in the country where the corporate headquarters is located, or where sales are made. The database covers the period 1990-2014. R&D expenditures by the food industry cover the period 1990-2012 and draws on OECD data (Business expenditure on R&D, BERD) for OECD and other countries covered in the OECD database on R&D statistics, and for others, from national estimates, where available. If not, expenditures are assumed to be zero (Fuglie, 2016).

[4] Fuglie et al. (2011) found that the largest 5-10 companies in each sub-sector of agriculture-related activities accounted for 80% or more of total R&D in the sub-sector. Fuglie (2016) found that the 23 top-tier companies accounted for over 70% of global private expenditure on agricultural R&D in 2014.

[5] Adding the global estimate of public expenditure on agricultural R&D from Beintema et al. (2012) to the estimate for private expenditure in Fuglie (2016), the share of the latter in the total is about 30%.

[6] OECD seeds schemes web site: www.oecd.org/tad/code/abouttheoecdseedschemes.htm.

[7] Pray and Fuglie (2015) found that technology policy (support, IPR, and access to national market) can have a significant influence on private agricultural R&D spending in emerging economies, including by foreign companies. They analyse the experiences of Brazil, China and India, contrasting the approaches and identifying the respective contribution of multinational versus national companies.

[8] See Box 6.1 in OECD (2015a).

[9] Pull-mechanisms reward successful innovations ex post, as compared to push mechanisms, which fund potential innovations ex ante (see Box 6.3 in OECD, 2013).

[10] For example the Tropical Agricultural Platform (TAP) (www.fao.org/in-action/tropical-agriculture-platform/background/en). Developed in this context, TAPipedia is an information sharing system designed to enhance knowledge exchange in support of Capacity Development (CD) for Agricultural Innovation Systems (AIS). It aims to be a global information system for good CD practices, innovation outputs, success stories and lesson learned.

[11] For example the International Panel on Climate Change (www.ipcc.ch/) and the Global Research Alliance on Agricultural Greenhouse Gases.

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Chapter 6. General policy environment for food and agriculture

This chapter consider the extent to which the general policy environment facilitates or impede innovation, structural change, and sustainable use of resources in food and agriculture. It covers policies that can facilitate investment, such as regulations, trade, finance and tax policies, as well as policies that foster infrastructure capacity, skills and education and thus facilitate innovation, structural adjustment and more efficient resource use in food and agriculture. Finally, the chapter identifies main knowledge gaps and consolidates recommendations to strengthen the general policy environment in key areas made in country reviews.

- Good public governance and trust in institutions facilitate innovation, yet even with less-than perfect conditions, it is taking place when profitable.
- Transparency and accountability, and consultation with stakeholders facilitate policy reforms and trust in regulations.
- Regulatory burden remains an issue in most countries, but several governments have started to modernise regulations to improve transparency and efficiency, and harmonise across jurisdictions and countries. Timely response to new regulatory issues remains a challenge.
- Core environment and resource regulations are needed for agriculture sustainability and productivity. The degree of sophistication of natural resource governance differs by country, with some facing significant weaknesses limiting the effectiveness of regulatory systems. Environmental regulation stringency is difficult to measure, in particular for agriculture.
- In most reviewed OECD countries, trade policy does not generally restrict access to modern technologies and farm inputs, but some farm commodity sectors are heavily protected from foreign competition in some countries. Tariffs for capital goods and intermediate goods are generally higher in emerging economies than OECD countries. There has been significant progress in trade facilitation since 2012. There are few restrictions to foreign direct investment in reviewed countries, except for agricultural land in a few of them.
- In most OECD countries, the banking sector and financial markets are well developed, and credit is accessible for food and agricultural firm that want to innovate, although access had become more difficult in the years following the 2007 financial crisis.
- In addition to supporting investment in private companies, most reviewed countries implement specific programmes to support investment in agriculture, and sometimes the food industry and the development of value-chains.
- Total tax rates as a percentage of profit range from 20% to 70% in reviewed countries, mainly due to differences in labour taxes and contributions. Farm income can be taxed as personal income or corporate income, depending on legal status. In a few countries, agricultural income benefits from special treatment, such as the option to smooth taxable income over time, or taxation based on sales or a lump sum. Fuel for agricultural uses benefits from lower tax rates in some countries.
- Countries increasingly use tax instruments rather than direct support to stimulate R&D in firms.
- Rural infrastructure and services are crucial for the competitiveness of the agri-food sector, but provision is a challenge in remote regions with low population density, in particular in very large countries but not only.
- Matching labour and skills demand from food and agriculture is a growing issue in many countries, which labour, immigration and education policies can help respond to.
- Agriculture-related education can contribute by becoming more attractive to students, anticipating new skills demand and adapting courses accordingly, offering long-life training to all workers in the sector.

Facilitating investment

The country reviews consider the extent to which the general policy environment facilitates or impede innovation, structural change, and sustainable use of resources, and is forward looking.

Good public governance and trust in institutions are important to facilitate policy changes, the acceptation of regulations and innovation, the development of contracts for marketing, the protection of property rights and the respect of rules regarding access to natural resources, the quality and safety of farm inputs and food products.

A number of reviewed countries achieve good public governance and trust in institutions, yet even in countries with less-than perfect conditions, innovation is taking place when profitable. Transparency and accountability, and consultation with stakeholders facilitate policy reform, as illustrated by the experience in Australia.

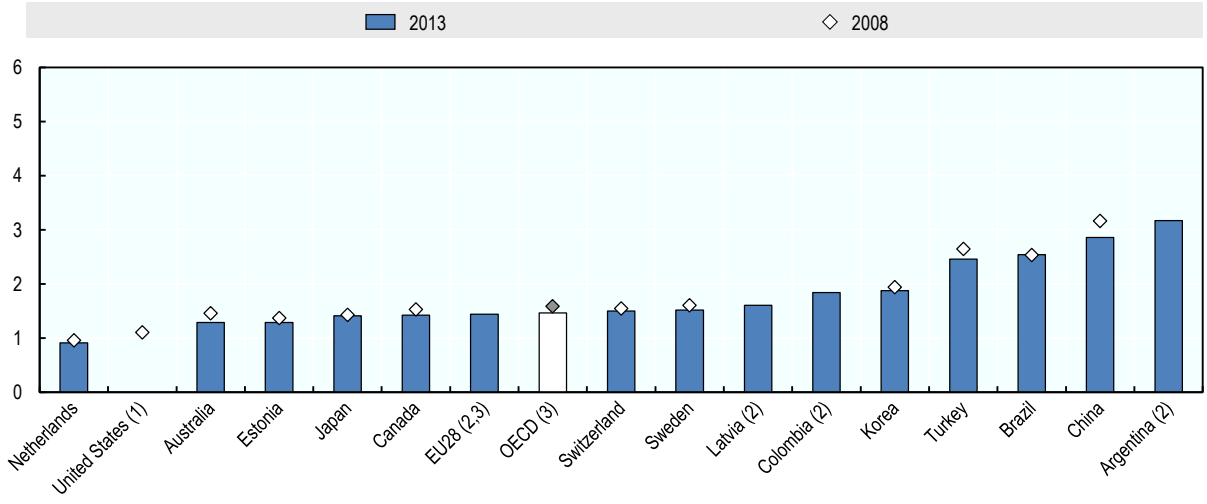
The general business environment, including sound macroeconomic fundamentals, clear regulations, competitive conditions in domestic markets, open trade policy, access to finance, and a tax system promoting investment, affects the competitiveness of both agri-food companies and farms. In most OECD countries, the overall policy framework is generally supportive of innovation, but country reviews identified some areas for improvement.

Regulatory burden is an issue for the agri-food sector in most countries, in particular regarding the complexity and timeliness of regulatory procedures for the approval of farm inputs, and food safety requirements. Business regulations have generally become more supportive of innovation over time. In particular starting a business has become easier in many countries (Figure 6.1).

Coherence between national and regional regulations is an issue in federal countries. For example, many natural resource and environmental regulations are under sub-national responsibility in Australia, Canada and the United States, often comprising very different approaches within the same country. Incoherence between local, regional and national level governance systems can be particularly problematic in the case of water as observed in the People's Republic of China (hereafter "China"). Transboundary conflicts around common resources across states or provinces can take a long time to resolve.

Figure 6.1. Product Market Regulation Index: Integrated index, 2008 and 2013

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



Notes: 1. For the United States, 2013 data are not available.
2. For Argentina, Colombia, EU28 and Latvia, 2008 data are not available.
3. Indices for EU28 and OECD are the simple average of member-country indices.
Source: OECD (2014), OECD Indicators of Product Market Regulation Database, www.oecd.org/economy/reform/indicators-of-product-market-regulation/.

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Environmental and resource regulations may impact agriculture productivity and sustainability, but there is no consistent effort to characterise how this is done. The OECD developed an environmental policy stringency index, but it does not reflect policies that may affect the agriculture sector.

Core natural resource regulations are however necessary to ensure that agriculture is productive and sustainable. In particular, robust water resource allocation regimes, which rely on a system of regulations defining water property rights, are necessary for a sustainable management of water resources in agriculture in regions and countries where agriculture relies on irrigation (OECD, 2010; 2015a). They contribute to the sustainability of the productivity of agriculture under climatic events like droughts or floods (OECD, 2016; 2017a). Recent promising initiatives have been introduced in reviewed countries to improve the management of water, including for agriculture (Box 6.1).

The degree of implementation of the regulations depends on the quality of resource governance systems. In particular, if some countries have more advanced and sophisticated water governance systems (Australia), others present gaps and inconsistencies in rural areas (China), limiting the impact of (even well designed) policies in the agriculture sector.

Land regulations also condition productivity and sustainability in agriculture. Depending on the overall land constraints, reviewed countries have set regulations to restrict agriculture land expansion to forested areas (Brazil, Colombia), to discourage agriculture land fragmentation (Turkey), or to prevent agriculture land conversion to urban use (Japan, Korea). While introduced for different purposes, these different regulations can all support sustainability objectives: forests provide a range of essential ecosystem services that

surpass those generated by agriculture, but agriculture production will also provide ecosystem services that surpass those associated with urban development.

Box 6.1. Examples of promising water policy initiatives to improve water management in agriculture

High-level policy calls have highlighted the need for agriculture to improve their management of water resources. In 2017, G20 agriculture ministers adopted a declaration and an action plan entitled "Towards food and water security: Fostering sustainability, advancing innovation" which includes a number of significant commitments to improve agriculture's water use and reduce its exposure to water risks.

Reviewed countries have recently introduced several promising programmes or regulations to improve their managements of water resources with particular emphasis on agriculture. These initiatives have combined sound policy choices with efforts to have effective policy processes.

As part of broader revision in the federal water governance system, following the 2014 major drought in the South, Brazil initiated steps to bolster the use of water charges for hydropower facilities and agriculture users. The water charges aim to help improve water allocation while helping recover regulatory agency recover charges. Following an extensive consultation with stakeholders, within states and with interstate river basins, it has initiated a gradual plan to implement higher water charges that will depend on river basins, supported by financial and transparent plans, focusing on large water users.

In 2014, amidst the most intense drought ever recorded, the US State of California introduced its first ever regulation of groundwater, the Sustainable Groundwater Management Act. This reform aims to address groundwater depletion, which is largely driven by irrigators, by 2042, while reducing other pumping related environmental damages. The regulation requires the formation of groundwater sustainable agencies (GSA) in each groundwater body. These agencies are charged with setting up plans to manage their groundwater. GSAs in defined medium or high priority groundwater bodies that do not set up and apply a plan in consistency with the legislation can face probationary actions by the state agency, which can temporarily take responsibility for the management of the groundwater body (setting plans etc.).

In 2018, the government of Canada and the government of the province of Ontario launched the Canada-Ontario Lake Erie action plan to address phosphorus pollution responsible for algal blooms and hypoxia zones in the lake. This programme, which aims at reducing Canadian phosphorus loadings by 40%, involves multiple approaches and advanced data assessments to arrive to a result. The plan is organised as a multi-partner programme, involving a wide range of actors in the basin, embedding regular evaluation of progress, continued engagement with stakeholders and allowing adjustment of the plans as needed.

Source: G20 (2017), "G20 Agricultural Ministerial Action Plan 2017- Towards food and water security: Fostering sustainability, advancing innovation", www.bmel.de/SharedDocs/Downloads/EN/Agriculture/GlobalFoodSituation/G20_Action_Plan2017_EN.pdf?__blob=publicationFile; Gruère et al. (2018), "Reforming water policies in agriculture: Lessons from past reforms", https://doi.org/10.1787/1826beee-en ; OECD (2017b), *Water Charges in Brazil: The Ways Forward*, http://dx.doi.org/10.1787/9789264285712-en; Gruère and Le Boëdec (2019), "Navigating pathways to reform water policies in agriculture", https://doi.org/10.1787/906cea2b-en.

Reviews of EU Member States show that common environmental regulations can trickle down differently and lead to different approaches. Accession to the European Union contributed to the fragmentations of environmental regulations in Estonia. The Netherlands has used incentives to complement environmental regulations to increase their

sustainability performance, but also had to abandon an innovative policy to reduce fertilisers due to incompatibility with EU competition rules. Sweden has implemented regulations that are more extensive and complex than those in other EU Member States. National regulations tend to set norms and standards for environmental and animal welfare well above EU requirements in the food and agriculture sector, particularly in relation to the types and permitted uses of pesticides, and the use of antibiotics in animal production, as well as animal welfare such as housing, space and husbandry practices. The EU accession process has also encouraged environmental regulatory development in Turkey although implementation, monitoring and assessment still need to improve.

Regulations on products and processes that aim to protect human, animal and plant health can also affect natural resource use. Other process regulations, like those governing organic farming, provide consumers with assurance of certain production practices and influence investment decisions.

In many countries, government bodies responsible for the implementation of regulations on agricultural chemicals and veterinary products, are different from those overviewing regulations on food products and processes. In countries with a federal structure, differences remain across states and between federal and state-level regulations, but there have been efforts at harmonisation. The Canadian review reports that the process of harmonisation between countries (e.g. the Canada-United States regulatory co-operation in Box 4.1 of OECD, 2015b) provides an opportunity to revisit internal differences. At the time of the review, Canada was also discussing the adoption of a Bill expanding the use of a regulatory tool, "incorporation by reference", that allows easier incorporation of standards and requirements created by an international standard setting body or adopted by another jurisdiction. This would help to avoid duplication and promote jurisdictional harmonisation.

EU Member States implement regulations that are mainly determined at the EU level. The Dutch review suggests using innovative approaches to reduce regulatory costs for governments, including partnering with the private sector in the management of sanitary and phytosanitary (SPS) regulations to build an interface between private voluntary standards and compulsory compliance regulation. The length of time for the approval of new products on the market differ widely among reviewed countries. For example, it takes 6 months in the United States and 4 to 5 years in the European Union (OECD, 2015c).

The principle that regulations should be science-based is widely shared, but some countries also take account of social and economic impacts, and consult stakeholders. Most countries have developed specific regulations for genetically modified (GM) products, generally based on the OECD risk assessment process, but authorisation procedures vary significantly. In Australia, the Gene Technology Regulator makes decisions on the development and use of GM organisms based on health, safety and environmental considerations, but the states regulate the commercial and marketing arrangements of GM crops. Since 2015, a Directive gives EU Member States flexibility to decide on the cultivation of GM crops on parts or all of their territory, under certain conditions, and either during the authorisation procedure or after the GM crop has been authorised at the EU level. In the United States, the Coordinated Framework for Regulation of Biotechnology aims 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. This framework also applies to products

generated by gene editing technologies,[1] which introduce very precise modifications. In the European Union, these products are regulated as GM products. At an OECD Conference on genome editing applications to agriculture, Argentina also presented a recent framework to assess these products.[2]

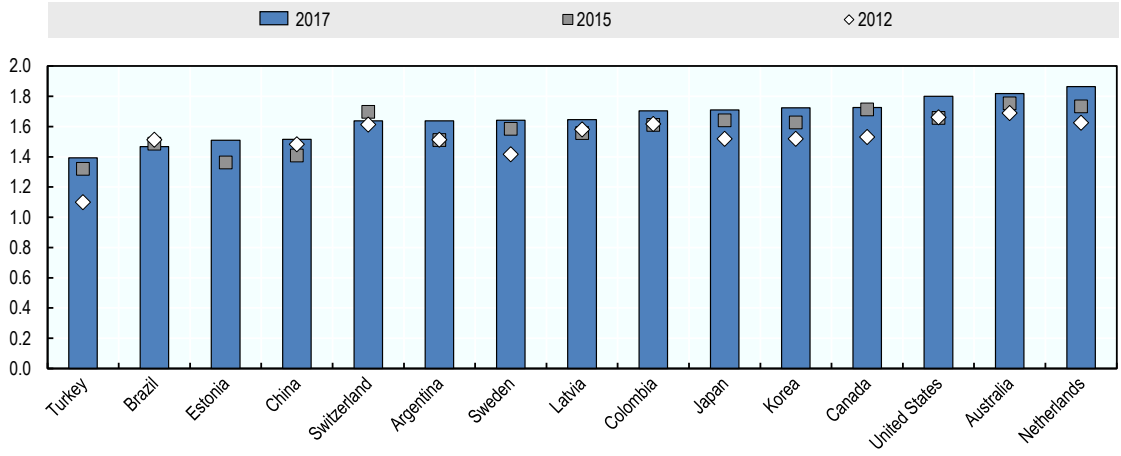
Trade policy does not generally restrict access to modern technologies and farm inputs (in particular in OECD countries), but in reviewed countries, some farm sectors are protected from foreign competition. In emerging economies like Brazil and China, tariffs for capital goods and intermediate goods are higher than in most OECD countries. This increases the cost of capital, inputs and machinery equipment needed to innovate, and thus affects the competitiveness of the agri-food sector.

In most countries, there have been progress in trade facilitation since 2012 (Figure 6.2). However, a deterioration in scores for information availability and involvement of trade community resulted in a decrease in the overall index for Brazil between 2015 and 2017.

According to the OECD index, regulatory restrictions on foreign direct investment (FDI) in food and agriculture are generally low in most reviewed countries (Figure 6.3). However, they are relatively high for agriculture in Korea and Brazil. In the latter, the restriction relates to the acquisition of rural land by foreign legal or physical persons. In particular, the share of land rented or operated by foreigners cannot exceed 25% of total rural area by municipality. While a net exporter of FDI and embedded knowledge in food and agriculture, the Netherlands is also very open to FDI.

Figure 6.2. OECD Trade Facilitation Indicators, 2012, 2015 and 2017

Scale from lowest (0) to highest (2) performance



Note: Arithmetic average of indicators on Information availability, Involvement of trade community, Advance rulings, Appeal procedures, Fees and charges, Formalities – documents, Formalities – automation, Formalities – procedures, Border agency co-operation – internal, Border agency co-operation – external, and Governance and impartiality.
Source: OECD (2017c), Trade Facilitation Indicators, www.oecd.org/trade/facilitation/indicators.htm.

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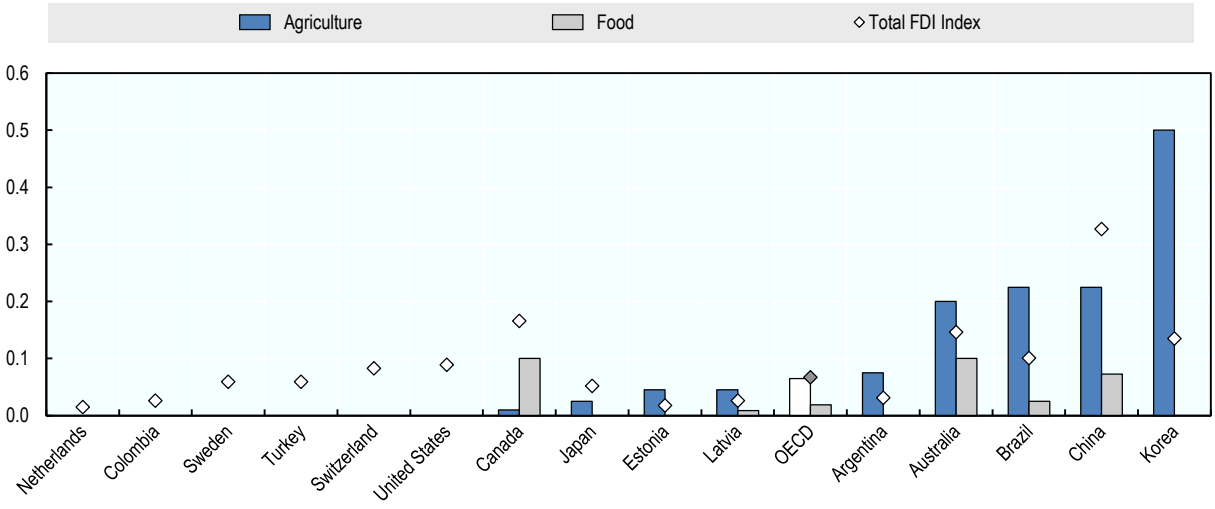
Figure 6.3. OECD FDI Regulatory Restrictiveness Index, 2016

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



Notes: 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. Indices for OECD are the simple average of member-country indices.
Source: OECD (2017d), "OECD FDI Regulatory Restrictiveness Index", OECD FDI Statistics (database), www.oecd.org/investment/fdiindex.htm.

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While OECD countries usually have a well-developed banking sector and financial market, **access to finance** has become an issue after the crisis. In some countries, farms have preferential conditions or investment grants (but not in the United States until recently), sometimes without a clear identification of market failure in credit market (clear market failure in Brazil). Some farm investment support is for the adoption of modern technology/building (Europe in relation to respect of EU regulations; Canada). Surveys may report difficulties in accessing loans, which are often linked to low income and profitability, and high debts, not necessarily market failures. Some countries provide investment support to farmers, and sometimes food processing companies. Credit mainly comes from traditional sources such as banks.[3] Some countries mention efforts to develop venture capital for innovative firms but the extent to which it benefits agri-food firms is not clear.

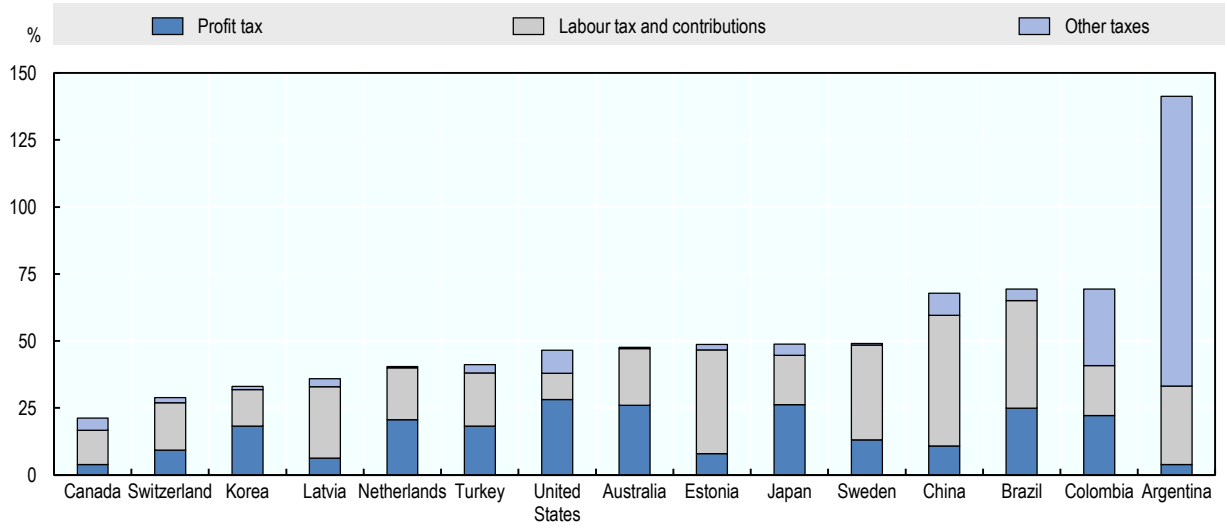
The **tax system** affects agri-food companies and farms in many ways. Total tax rates as a percentage of profit vary from 20% to 70% in reviewed countries (Figure 6.4). Some countries have reduced rates for smaller enterprises (e.g. Canada), which apply to many food processing firms and farms. Many countries have specific provisions for farmers, usually to reduce income tax, allow for income smoothing, and to facilitate farm transmission. Reduced rates for taxes on fuel used in agriculture are also common. In Brazil, agro-food exports benefit from tax preferences as all exports of raw material and semi-processed products destined for exports.

Several countries undertook changes in taxation systems in recent years. The Australian tax system has been undergoing significant changes since 2010; some with possible implications on investment in the agricultural sector. In Estonia, the use of environmental taxes and charges has been increasing since 2005. As discussed in Chapter 5, many

countries have increased R&D tax incentives in the last decade, and Estonia is one of the very few OECD countries that does not use this type of incentives.

Figure 6.4. Total corporate tax rate, 2017

As a percentage of profit



Note: The evaluation uses a concept of a "case study company" defined on the basis of a set of criteria, including the legal form of business (limited liability), start date of operation (January 2012), geographic location (country's one or two largest business cities), origin of ownership (100% owned by domestic natural persons), type of activity (general industrial and commercial), size (own capital amount, number of employed, turnover, etc.). The total tax rate is the sum of taxes and contributions payable after accounting for allowable deductions and exceptions related to commercial profit of businesses before all taxes borne. The groups of taxes covered include: profit or corporate income tax; employer's social contributions and labour taxes; property taxes; turnover taxes and other (such as municipal fees and vehicle and fuel taxes).
Source: World Bank Group and PwC (2017), Paying Taxes 2017 - The Global Picture, PwC, World Bank and IFC, www.doingbusiness.org/data.

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Developing capacities and services

Good **infrastructure** is crucial for the competitiveness of the agri-food sector, as it reduces costs and facilitates marketing. It is a major issue for large countries. The most serious issues are in Brazil, but also Turkey and parts of Australia and Western Canada, where large production areas are far away from consumption and export places. Water management infrastructure (irrigation or drainage) is the main agricultural-specific infrastructure. The reviews suggest assessing future demand for infrastructure, taking climate change and water constraints into account.

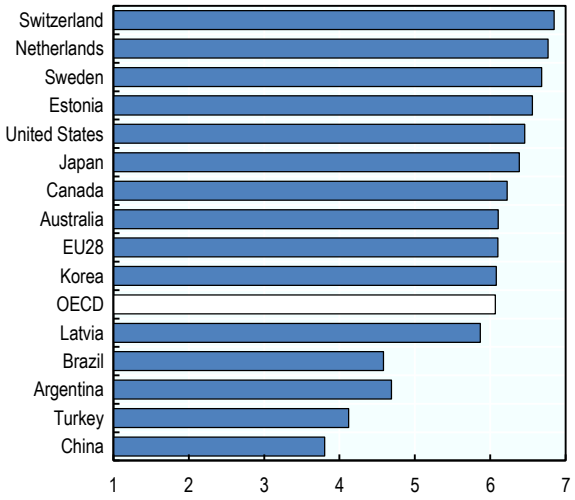
Providing adequate infrastructure and services in remote rural areas remains a challenge in most countries, as costs per user are high in these areas with low population density. Technological and organisational innovations can help, such as faster trains helping connect rural areas to job markets, on-line work, new energy sources able to operate independently of the electricity grid, E-services and joint services). Information and Communication Technologies (ICTs), including digital technologies, offer promising solutions to deliver services in rural areas, connect people and markets, and facilitate

traceability along the food chain. While ICT use is very high in some OECD countries, it is less widespread in emerging economies (Figure 6.5).

Government's effort to revitalise rural areas in Korea are summarised in Box 6.2. In Estonia and Latvia, EU structural funds contributed to a large part of investment to improve rural infrastructure. Other countries like Brazil consider Public-Private Partnerships (PPP) to help finance much needed infrastructure investments. Canada developed PPP Canada, a Crown corporation working with all partnerships to support greater adoption of PPPs in infrastructure procurement. In this country, a large number of federal and provincial ministries and government agencies contribute to rural development so a number of mechanisms have been put in place at the Federal level to ensure coherence across policy areas that have an impact on innovation in food and agriculture. They include FTP government committees, interdepartmental reviews and regional-federal councils.

Figure 6.5. Global Competitiveness Index: Total index of Information and Communication Technology (ICT) use, 2017-18

Scale from lowest (1) to highest (7) quality



Note: Total index of ICT use is the aggregate of the following indicators: Individuals using Internet refers to the share of individuals using the Internet; Fixed-broadband Internet subscriptions refers to the fixed-broadband Internet subscriptions per 100 population; International Internet bandwidth refers to the international Internet bandwidth (kb/s) per Internet user; Mobile-broadband subscriptions refers to the active mobile-broadband subscriptions per 100 population. All indicators were converted to 1-to-7 scale using a min-max transformation. Indices for EU28 and OECD are the simple average of member-country indices.
Source: World Economic Forum (2017), *The Global Competitiveness Report 2017-2018: Full data Edition*, http://reports.weforum.org/global-competitiveness-index-2017-2018/.

StatLink https://doi.org/10.1787/888933998842

Box 6.2. Comprehensive rural development policy and household income statistics in Korea

A balanced regional development has been a major policy issue in Korea as the economic growth has concentrated on urban areas and the manufacturing sector, increasing the income gap between rural and urban households.

Rural development policy in Korea evolved from the participatory community based programme in the 1950s (The Saemaeul Movement) to a nationwide comprehensive programme, widening the scope from agriculture to non-agricultural industries.

The Saemaeul (new village) Movement was implemented as a nationwide comprehensive development project including improvement in rural infrastructure and residential environment as well as income generation activities such as the introduction of cash crop production and building factories. The important aspect of the Saemaeul Movement was a co-operation of the government and the rural residents using both government budget and private funds.

In the 1980s, rural development policy shifted to a more state led comprehensive rural development framework. Increased government budget in the 1980s and 1990s enabled the central government to develop roads, communication facilities, and water sources in rural areas, and to improve educational, medical and welfare systems. The major goals of the rural development policy during this period were to improve the living conditions in rural areas and to increase the rural income through creation of off-farm activities.

In the 2000s, the paradigm of the rural development policy was extended from agricultural production to settlement and recreation. The government focused on enhancing the amenity functions of rural areas, boosting environmental protection, and emphasising agriculture's role for preservation of the national land. The government has promoted an autonomous development strategy that strengthens local competencies and utilises local resources through projects. The government enacted the Special Act on Improving the Quality of Life in Rural Areas and Rural Development Promotion in 2004 to attract human resource and economic activity in rural areas.

According to the action plan in 2016, investment and financing were focused on the projects such as revitalisation of rural hubs, village maintenance, housing maintenance, water use improvement, and safety management of rural areas. The National Standards for Rural Area Services set comprehensive and concrete policy targets in many areas (health and welfare, education, settlement condition, economic activity and job, culture and leisure, and safety) to guarantee a high quality of life for rural residents. The assessment of policy achievement in 2016 shows that most areas still fell short of the standards except for emergency service and broadband convergence network..

Another important policy aspect to assess the achievement of rural development policy is the development of statistics of farm household including both farm and non-farm income. The Farm Household Economy Survey, which was originally established in 1953, provides a complete income structure of farms and provides basic information for policy makers to assess the farm household income situations.

Source: OECD (2018a), *Innovation, Agricultural Productivity and Sustainability in Korea*, https://doi.org/10.1787/9789264307773-en.

Ensuring the **labour and skills** supply meets the demand of the food and agriculture sector is a widespread issue. In primary agriculture, the farm population is decreasing and ageing in many reviewed countries. Wages are generally lower than in other sectors for equivalent skills, and rural areas often lack attraction for young people. At the same time, challenges

for the sector such as uncertainty about future policies and market developments, stronger regulatory constraints, increasing competition, and concerns about low profitability prospects may discourage new entrants. Low wages and hard working conditions also cause labour shortages in companies along the food chain, such as abattoirs. Finally, some activities, such as fruit and vegetable picking and processing, require seasonal labour. Shortage of labour reinforces interest for labour-saving technologies, including digital ones, which are developing fast in countries with a competitive-agricultural sector like the Netherlands and the United States, but also China and Japan.

In response to seasonal needs, most reviewed countries except Argentina and Brazil have less protective regulations on temporary forms of employment than on regular employment. Immigrants make a significant part of seasonal labour, but increasing general restrictions on immigrations in many countries have limited access to this source of cheap labour, and thus threatened the competitiveness of some farm sectors (horticulture). Reviewed countries have implemented specific provisions for seasonal immigration. They include temporary immigration schemes allowing employers to hire foreign nationals when qualified citizens are not available (Canada and the United States), schemes providing for sponsorship of employers for foreign workers, including skills training components (Australia), regional programmes to attract newcomers in regions with shortages, and the removal of impediments regarding labour costs for employing foreign workers (Estonia).

At the same time, skills needed in the food and agriculture system are changing and becoming more diverse, and sometimes less specific to the sector (e.g. digital and management skills). This requires retraining existing staff (or recent immigrants like in Sweden), and working with the education community to adjust education programmes to industry demand. An Estonian programme encourages talents, who study or work abroad, to come home. As skills needs are changing fast, it is important to offer and facilitate life-long training.

More generally, the food and agriculture sector benefits from systems improving job placement, offering training opportunities and improving information on job offers and requirements, whether general or sector-specific. Programmes supporting business in rural areas, providing incentives to locate in rural areas with labour and skills shortages or facilitating relocation should benefit employment in rural food and agriculture activities. In Turkey, a programme supports entrepreneurship and training for women in rural areas.

Agriculture or green education has an important role in improving future skills match. In reviewed countries, agriculture education is generally an integral part of the general education system, even when under the umbrella of the ministry in charge of agriculture or concentrated in specific agricultural institutions. It means that it shares the strengths and weaknesses of the general education system. This suggests the relevance of OECD information on general education and skills for the sector. In addition, the importance of sciences in national education is a good indicator of innovativeness and society's acceptance of innovation, which is relevant for agricultural innovation.

Even when the education system is modern and performant like in Australia, Canada, the United States, the Netherlands, Sweden and Estonia, attracting national students in agriculture-related topics is a challenge, although these countries attract foreign students. In emerging economies, however, agricultural studies remain attractive, especially in countries with a large agricultural sector like Argentina and Brazil.

In addition to improving sectoral competitiveness, suggestions to improve attractiveness include the promotion of agro-food careers that emphasise the opportunities for high-

skilled and knowledge intensive jobs, as outlined in the Australian review. In the Netherlands, demonstrating the job opportunities and emphasising the link to food security and nature management, beyond primary agriculture helped attract non-traditional agricultural students. As the sector requires a wider set of skills (such as nature management, food and health, digital technologies, management and accounting), agriculture education interests a broader range of students that do not have a rural background. The US review suggests promoting agricultural vocational education among non-traditional students from more urban background.

At all levels, another challenge is to retain students in the sector (as mentioned in Estonia, Australia and Canada) as agricultural skills can be transferred in other sectors that offer better salaries and are as diverse as mining, forestry, construction, accounting or marketing.

Finally, agriculture education needs to adapt to industry's needs and students' choices. Discussion with the industry and other education organisations helps understand and plan future needs, as done in the Netherlands with the Top Sector and the Green Table. A common finding is the benefit for innovation of strengthening management and marketing courses, alongside more technical topics.

Main knowledge gaps

A number of composite indicators score and rank countries' policies and regulations enabling the business environment. They include the World Economic Forum (WEF) Global Competitiveness Indicators, the World Bank Group (WBG)'s Ease of doing Business indicator, and the OECD Product Market Regulation indicators. More recently, the WBG developed an Enabling the Business of Agriculture, which reflects mainly the situation in developing countries. Similarly, the OECD and IFPRI developed for a number of developing countries Agricultural Growth Enabling Index (AGEI) (Diaz-Bonilla et al., 2014), which the OECD then updated and refined (OECD, 2017e).

While the OECD developed an environmental stringency indicator, it does not take account of all dimensions of environmental issues related to agriculture. Discussion on the development of agriculture-specific environmental stringency indicators have started in the OECD, raising methodological issues regarding the scope (e.g. would agri-environmental policies be included?), and aggregation method, including the determination of weights for different environmental aspects.

Country reviews report several components of these indicators as a basis for evaluating specific framework policy areas. But they do not necessarily reflect the extent to which the general policy or regulation affect positively or negatively drivers of food and agriculture performance. Even at the national level, this issue in not well documented.

It is also difficult to evaluate which are the most binding constraints. Some countries conducted surveys on impediments to investment, in which respondents rank the main obstacles.

As for other sectors, the impact of competition on innovation in food and agriculture is not well documented, although the US review discusses the impact of concentration in input industries and the exemption of co-operatives from anti-trust laws on competition and prices. OECD (2018b) explores increasing concentration in markets for seed and GM technology and its impact on prices and innovation. Overall, there is no strong evidence that concentration in these markets is detrimental for innovation.

Regarding regulations on products and processes, some explicitly restrict specific innovation (in particular regarding production methods), but other regulations (e.g. on food safety and traceability; environmental constraints) stimulate the innovation system to find solutions.

The rationale for maintaining agriculture preferential treatment is not regularly evaluated. In recent years, the impact of taxation on agriculture has not attracted much interest in governments and academic circles.

The development of rural areas is an important objective in many countries, but it was beyond the scope of these reviews to have in depth analysis of this complex and multi-dimensional topic.

The OECD has a lot of information on education and labour but none is specific to agriculture. There is however good information on agricultural education at the national or institution level. Boundaries of agriculture education may, however, differ by country. One issue is to better understand the performance of agricultural students in the job market.

Recommendations to improve the general policy environment

This section consolidates the recommendations made in country reviews for various non-sectoral policy areas, and which are included in the country notes of Annex B. These policies aim to facilitate investment, and improve human and infrastructure capacity, and thus enable innovation, adjustment and sustainable resource use in food and agriculture leading to productivity and sustainability improvements.

Improve information on the link between general policies and agriculture to guide decisions

- Policy improvement requires more efforts to measure and assess the impact of general policies on food and agriculture. This concerns the development of appropriate data and methods. For example, methods for measuring environmental sustainability metrics need improvement.

Improve the policy and regulatory processes to facilitate investment

- Continue improving governance and policy coherence, and building trust in institutions. This includes defining strategic plans that ensure co-ordination between policy areas, and clarify responsibilities across levels of government and organisations; consulting with stakeholders; developing systematic evaluation procedures; and improving communication about policy action. If this is an issue, strengthen the enforcement of contracts and IPR.
- Modernise regulations to make them clearer, transparent, easily accessible, more coherent across jurisdictions. They should also become more flexible and responsive to industry and consumer needs, and anticipatory of science and technology development, and changes in public perception. Explore the use of more outcome-based regulations. Review progressively current regulations to minimise compliance costs and time, by reducing unnecessary burdens, e.g. reduce length and simplify procedure, ease regulatory burden for start-ups, reduce entry barriers.
- Strengthen regulatory services to business: build a platform, single desk containing all relevant information.

- Strengthen regulatory collaboration between and within countries to reduce regulatory heterogeneity.

Ensure non-sectoral polices improve the functioning of agri-food markets and trade

- Reduce tariff protection on industrial goods and capital to facilitate investment and innovation. Implement effective competition policy, including in the food chain. In particular, ensure fair competition between co-operatives and other providers of inputs and services.
- Explore export opportunities and in small countries, promote a regional approach to trade diversification.
- Review the scope for trade facilitation, e.g. using digital technologies.
- Promote risk management and ensure tools are available.
- Improving market transparency and efficiency for products would improve competitiveness and thus investment.
- Improve the functioning of input markets, thus improving access to innovative technologies, by removing distortions and impediments, enforcing competition policy and identifying market failures (e.g. in credit, land or water market) and working with input providers and users to identify supply, demand and constraints, and design solutions.
- Remove impediments to farm transmission.
- Facilitate access to capital by placing information on support programmes on a single platform, simplifying programme architecture, and exploring options for non-traditional sources of financing, such as venture capital and PPPs.
- Focus public support to investment in areas where financial market fail to provide funds, and in areas contributing to overall innovation and economic objectives (e.g. climate change, bioeconomy).
- Simplify taxation, in particular indirect taxation, to improve transparency, and fairness, and facilitate compliance. Ensure taxation is not so high that it discourages investment and participation in labour markets. Ensure reduced tax rates to small businesses do not prevent them from growing. Ensure taxation does not impede farm transmission.

Align policies and regulations towards sustainability improvements

- Evaluate environmental regulatory stringency for agriculture to assess the role of regulations and their effectiveness.
- Realign policy incentives towards environment and resource sustainability, removing environmental harmful subsidies such as fuel tax rebates, and using taxation or market mechanisms to meet environmental objectives.
- Improve the governance and management of natural resources, by strengthening environmental laws and regulations that define responsibilities and rights, identify and tackle local conflicts. Improve compliance, including using modern technology

but also by providing enough financial and skills capacity to agencies in charge of monitoring compliance.

- Target investment support to innovation, sustainable outcomes.

Develop rural infrastructure and services to improve connection

- More effective and forward-looking planning and strategies for development and maintaining rural infrastructure, drawing on assessment of (future) needs and evaluation of past policies. In particular, integrate environmental and climate change consideration in these plans (both ways), e.g. irrigation, production changes, mode of transport, contribution of agriculture to climate change mitigation.
- Simplify governance and improve co-ordination between ministries and levels of government.
- Improve connectivity in rural areas, in particular by increasing access to digital technologies.
- Develop green energy and facilitate the development of bio-based products, when opportunities exist.
- Develop innovative ways to deliver services. Facilitate co-operation among rural dwellers to maintain infrastructure systems (irrigation and drainage in particular) and maintain rural attractiveness.

Address labour and skills need in food and agriculture

- Implement more responsive and flexible labour and immigration policies to facilitate labour force moving in areas with strong demand.
- Ensure training and re-training programmes respond to needs (including immigrants, women, but also innovation skills). In particular, facilitate access for seasonal workers. Provide services for job placement and relocation.
- Set-up targets for agriculture education that reflects needs (skills, population trends) at the national and international level when relevant.
- Implement mechanisms to make agriculture education more attractive and responsive to changing skills needs in the labour market, and students' choices. These include reviewing needs regularly in consultation with all stakeholders and across education institutions, adapting curricula and creating new ones, integrating better new topics, such as management and accounting, digital technologies, animal welfare, health, climate change, and building bridges with non-agricultural education.
- If not already done, increase exposure of agricultural science specialists to social sciences 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.
- Promote agriculture education to change traditional public perception, and be more proactive in reaching non-traditional agricultural students. In some countries, ensure wider access. Modernise vocational training. Facilitate industry funding of

training and education. Adjust public funding to reflect objectives based on estimated needs.

Notes

[1] Genome editing refers to a set of techniques in which specialised enzymes have been modified and can insert, replace or remove DNA from a genome with a high degree of specificity.

[2] The OECD Conference on Genome Editing: Applications in Agriculture, Implications for Health, Environment and Regulation, was organised in Paris, 28-29 June 2018 to explore the safety and regulatory considerations raised by genome edited products, with the aim to favour a coherent policy approach to facilitate innovation involving genome editing (www.oecd.org/environment/genome-editing-agriculture).

[3] See Survey of food processing firms in the Canada review (OECD, 2015e).

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Chapter 7. Policy coherence in food and agriculture

This chapter analyses policy incoherencies found in country reviews and related analysis, which slow or prevent progress towards improved productivity and sustainability in food and agriculture. It described responses taken by some of the reviewed countries, identifies main knowledge gaps in this area and suggests possible approaches to minimise these policy incoherencies.

- Reviewed countries all display some type of policy incoherence with respect to agriculture innovation, productivity and sustainability, but some are more important than others.
- Incoherence in the strategic policy objectives is more problematic in that it leads to continued divergence of policies.
- Incoherence between agriculture policies and other policies, from lack of policy co-ordination, and the reduced role or exemption of agriculture in other policies, can generate barriers to progress on productivity and sustainability improvements.
- Incoherence among agriculture, innovation or environmental policies, which may result from the lack of co-ordination, insufficient *ex ante* and *ex-post* assessments, can impede on their effectiveness and in some cases create additional negative outcomes.
- Incoherence in policy approaches, such as piecemeal policies focused on certain crops or certain regions can also become problematic.
- Some of the reviewed countries have explicitly considered policy incoherencies when revising policies; others rely on evaluations embedded in policy making to avoid major inconsistencies.
- Some of the reviewed countries are also increasingly encouraging the adoption synergistic policies, which incorporate productivity and sustainability objectives

By assessing government policies' propensity to encourage food and agriculture productivity and sustainability, the reviews identified areas for improvement, but also highlighted a number of policy incoherencies. These incoherencies slow or prevent progress towards the sector's improved productivity and sustainability. This section explores the findings from the reviews and additional analyses, and suggests possible approaches to cope with these incoherencies.

Policy incoherence slows progress towards agriculture productivity and sustainability

There are different types of policy incoherencies, depending on their scope and the degree of divergence they imply. First, in terms of scope, policy incoherencies may be caused by misaligned general policy goals, divergent policy choices across policy areas (e.g. agriculture and education), inconsistencies within a policy area (e.g. agriculture policies), or incoherent approaches (e.g. direct support favouring a particular crop or farm practice). For instance, a government setting divergent but ambitious agriculture production and environmental goals differs from a case where a government programme encourages certain types of agriculture technologies or practices supporting productivity without accounting for sustainability.

Second, the impact of policy inconsistencies depends on the degree of divergence they imply, from neutralising to counteracting or slowing down progress towards agriculture productivity or sustainability. For example, depending on its design, an environmental regulation may slow down or ban the adoption of productivity-enhancing technologies sought by another government department.

Lastly, general and relatively unambiguous policy inconsistencies differ from those that will vary depending on the context (OECD, 2019a). For instance, a general inconsistency

is found in countries that support renewable energy while setting tax concessions for fossil fuels (OECD, 2017b). In contrast, certain agricultural or environmental policies, such as a risk management policy or a policy to conserve biodiversity may counteract against sustainability or productivity improvements (respectively) depending on the specific instrument used and context of application.

The causes of policy incoherencies also vary. They might result from unintended information asymmetries across government bodies or from explicit competing government objectives or priorities. They may also be due to irremediable incompatibility between past policies and new objectives or to changing political cycles with asynchronous policy changes. Governments seeking subsidiarity may induce incoherence across jurisdiction. Finally yet importantly, governments seeking policy coherency across certain objectives may create incoherencies with other objectives.

A close examination of the reviews (Table 7.1) shows that all the reviewed countries exhibit at least one type of policy incoherence with respect to agricultural productivity and sustainability improvements objectives, but that their scope differ. If most examples of inconsistencies fall into a particular policy area (innovation or agricultural policies), other types of inconsistencies are found. The following subsections examine the different types of incoherence found, with the objective of understanding their nature, their cause and their significance.

Table 7.1. Examples of policy inconsistencies impeding agriculture innovation, productivity and sustainability in reviewed countries

	Among general policy goals	Across policy areas	Within policy areas	Among policy approaches
Argentina		Taxing tobacco for health and using fund to subsidise tobacco producers. Spending on soybean R&D and innovation and taxing their exports	Encouraging market driven agricultural growth without considering environmental effects	
Australia		Participants to the Working Holiday Maker Programme do not work where there are labour shortages	Regulatory inconsistencies and particular features of intellectual property protection lowering private investment in R&D	Inconsistent water access, food and chemical regulations across jurisdictions
Brazil	Agricultural growth objectives differ from fundamental societal objectives	Ineffective regulations of credit market and agricultural support to credit	Farm support to non-commercial farms reduces incentive to increase efficiency and impedes on structural adjustment	
Canada		Difference between innovation in agriculture and broader innovation objectives		Inconsistent budget procedures for public and private actors to apply for funding
China		Incoherence between environmental and agricultural policies	Largest spending on R&D in GM crops without commercialisation	Support concentrated on some commodities
Colombia		Limited participation to tertiary level agriculture education does not reflect the sectors' importance	Inconsistencies between current usage and actual suitability of agricultural land create land use conflicts	
Estonia	Alignment between innovation and growth strategy over time		Support organic without considering marketing chain development	
Japan		Incoherence between environmental and agricultural policies	Export promotion and the payments for non-viable crops such as feed rice	Differences in support level by commodity
Korea		Separated water management for agriculture from other uses Commodity specific support incoherent with productivity social and environmental objectives	Income support payment in the absence of income declaration requirement for cereal farmers	Differences in support level by commodity
Latvia		Regulations facilitate seasonal work, but taxes reduce the incentive for labour participation	Support organic agriculture but not processing: organic milk sold as conventional products	Provides coupled support to specific commodities
Netherlands		Top Sector innovation strategy not fully aligned with EU regional cluster policy	Tax incentive for private research reduces funding for public R&D, including on public goods	
Sweden			Mismatched research with needs of the sector	Incoherence in rural development policy programmes nationally
Switzerland			Support for cattle in less favoured areas intensifying environmental pressure from livestock Efforts to reach agri-environmental targets accompanied by increased energy use	
Turkey		Incoherent regulations governing land transfers, land consolidation, and land protection	The structure of agricultural producer support constrains long term productivity	
United States		Mismatch between efforts on secondary and tertiary agriculture education	Agriculture intensification takes place on land that is not enrolled in agri-environmental programmes	Support focused on "white" commodities deterring on others

Source: Country reviews.

Incoherencies in general policy goals

In some reviewed countries, the government has set multiple strategic documents and plans that hamper overall food and agriculture policy coherence. In Estonia for instance, the agricultural growth strategy has a different timeline than the innovation strategy, but the overlapping area of agricultural innovation is only featuring on the innovation side. Priorities on innovation have changed at a different pace than agricultural policies.

Governments may also promote policy goals that are not always compatible with each other and with the pursuit of improved productivity and sustainability in food and agriculture. Countries like Brazil support the development of agriculture for economic growth but they also support more sustainable land use, two goals that may not always be compatible in the way they are undertaken. The People's Republic of China's (hereafter "China") past self-sufficiency policy objectives, which led to an expansion of grain productions, contributed to the deterioration of natural resources and the environment, triggering the revision of the national food security strategy in 2014. Argentina's agriculture innovation facilitated the expansion of soybean areas, leading to deforestation to relocate displaced livestock production.

The cause of these incompatibilities may result from the lack of co-ordination or cohesion across areas of governments when developing plans, lack of strategic planning, and/or from the superposition of different policy strategies over time. While a new government may propose a new strategy for the agriculture sector and beyond, it will need to apply policies that followed past strategies as long as they remain in place.

Incoherencies across policy areas

A benefit of reviewing policies by applying the food and agriculture productivity-sustainability framework is that it allows an assessment of the links between non-agriculture policies and the sector's productivity and sustainability. Findings from the reviews suggest that there are multiple incoherencies across policies that may affect food and agriculture performance.

As shown in Table 7.1, multiple types of incoherencies were reported in reviewed countries between agriculture policies and education, finance, labour, competition, innovation, energy, environmental or natural resource policies. Some incoherencies result from mismatch of efforts with policy needs; others result from incompatible objectives, misaligned or counteractive policies.

Incoherencies between agriculture policy and environmental and resource policies are of particular interest, in that they may create a conflict between sustainability and productivity growth objectives. As discussed in Chapter 6, existing literature suggests that environmental regulations have mixed effects on productivity; in some cases, they may enhance productivity.[1] Still, as discussed in Chapter 5, the level of agriculture development matters; countries in the process of developing agriculture may place higher emphasis on policies supporting investment in agriculture production while lacking in strength and implementation of their environmental and natural resource policies.

The cause of incoherencies may once again be multiple. In addition to insufficient policy co-ordination, the relatively limited attention given to agriculture and rural areas in general policy, and the fact that agriculture is set as an exception (or exempted from some policies and regulations) are sources of explanations for these incoherencies in certain countries. Agriculture education or agriculture innovation do not carry much importance when considering priorities for education, taxation, labour or credit policies, especially in

countries where the sector's contribution to the overall economy is minimal. While the cultural and institutional context or the national definitions of food security may explain the exceptional status of agriculture, it might deter agriculture's productivity and/or sustainability efforts. For instance, exempting co-operatives from competition policies while giving them the power to distribute support will result in less transparent policy and potentially biased policy results. Similarly, exempting agriculture from GHG emission regulations is questionable especially in countries where the sector accounts for a large share of national emissions.

The impacts of these cross-policy divergences vary. They may be remediated by changing one or more policies. Still, the fact that agriculture is either of limited importance or in some cases given a special status may make those divergences difficult to redress.

Incoherencies within policy areas

The most common policy incoherencies found in the reviews are within agriculture or innovation policies. These incoherencies are primarily the result of incompatible policy objectives, near-sighted policy efforts (focusing on one area not another) or the combination of the two. In particular:

- Several countries were found to have unbalanced innovation policy efforts. For instance, they may support a high quality research, without providing incentives to consider needs and supporting adoption, or they may constrain their research pipelines with complex regulations (China).
- Countries such as Estonia and Latvia support organic production without considering the lack of infrastructure to process such products, losing opportunities to escalate on the value chain.
- Many of the reviewed countries spend much of their efforts to support commodity specific agricultural production, while spending much less on the general services supporting agriculture and on the provisions of agriculture public goods (Chapter 5).

Agriculture policies aiming towards improved sustainability may focus on some issues, neglecting others. For instance, the management of natural resources will often take priority compared to the negative impact of intensive agriculture systems on ecosystems. This is despite the fact that natural resource management can be considered closer to a private good, with market solutions, as farmers will benefit from it directly, while air or water quality is a public good, on which they do not gain any benefits. Reducing visible pollution is also given priority compared to an invisible one; e.g. surface versus groundwater nitrate pollution, or air pollution due to pesticides or fertilisers versus greenhouse gases, without accounting for the different impacts.

More specifically, recent OECD studies have identified policy synergies and trade-offs between climate change adaptation, GHG mitigation and agriculture productivity (Lankoski, Ignaciuk and Jésus, 2018). As part of this work, a review of relevant policies in the Netherlands found that the government prioritised policies supporting agriculture competitiveness and greenhouse gas (GHG) mitigation, leaving farmers responsible for adaptation. It also showed the influence of EU-wide policies in national policy coherence, but that societal demands for animal welfare might in some cases result in trade-offs with competitiveness and GHG emissions (Ignaciuk and Boonstra, 2017). An *ex ante* farm level simulation with applications in Finland and the Midwest United States found that several policy instruments, such as green set-aside payments or investment subsidies for adaptive

capitals, send signals that impede the achievement of at least one of the three objectives (productivity, mitigation and adaptation) (Lankoski et al., 2018). The study also shows that inconsistencies in this area are often context dependent (ibid.).

The main causes to most these incoherencies are asymmetric information and near-sighted policy setting. Both causes may partially result from the absence or insufficient robustness of *ex ante* and *ex post* policy assessments. Policy incoherence that seemingly results from the juxtaposition of past policies with new ones would be avoided with proper *ex-ante* assessment of new policies. The design of policy evaluation may also be near-sighted and therefore unable to identify the problem. Many policy evaluations focus only on the implementation of intended objectives, rather than on the results, accounting for some specific dimensions and ignoring others.

The value of policy assessment is particularly evident in cases where policies that aim to support productivity and sustainability fail unintentionally. For instance, in the United States, a programme supporting irrigation efficiency, thereby aiming to contribute to sustainability and productivity, was later found to increase groundwater use, due to farmers' behavioural response (OECD, 2015). Such assessments are also necessary in cases where the effect of one instrument is ambiguous and context dependent, such as when land use restriction is needed to conserve biodiversity but may lead to intensification of agriculture production with other environmental problems (Argentina and Brazil).

Incoherencies in policy approaches

The last type of incoherencies originate from inconsistent policy approaches. These inconsistencies are found in countries where policies are customised to a particular region, subsector, production process, or stakeholder groups, but that interactions or competition among those regions, subsectors, production processes, or groups make these policy differences at least partially problematic with regard to agriculture productivity and sustainability.

- Such incoherency can be seen in cases of federal countries, or countries aiming for subsidiarity. An example in Table 7.1 is the case of Australia's regulatory heterogeneity for agriculture products and inputs. While this heterogeneity is due to limitations in federal government oversight, it may prevent some states to operate in the level-playing field, constraining agricultural productivity nationally.[2]
- A number of countries concentrate agricultural support towards certain commodities (Chapter 4), which creates an incentive to keep producing those and not others, which may prevent the development of other productive and income generating activities that could be more sustainable and resilient.
- In countries with process-based regulations, the evolving scope of regulation for new genetique techniques or chemical inputs may create loopholes and slow R&D efforts. Banning the use of a chemical will lead to the development of others potentially as toxic chemicals. Regulating new technique will lead to getting back to older ones, to sometimes arrive at the same result.[3]

The causes of these inconsistencies may be due to existing legislation (federal countries), or to political choices in response to demand by groups of constituents, from production groups to civil society. In the first case, it may be difficult to change the situation; in the second such incoherencies may be dependent on the political cycles.

Responses to policy incoherence

Several countries have explicitly sought to address policy incoherencies. Starting in 1992, the European Union's Common Agriculture Policy has expanded in scope from pure agriculture production to support for public goods. This has led to some progress in some areas, but not enough in others. Recent efforts in Canada, the Netherlands or Sweden aimed to develop broader food policies that may cover agriculture, food, but also related energy, environment, natural resource, animal welfare and health issues. It is too early to tell how effective and lasting these efforts will be.

International organisations have also expressed calls and developed plans to improve policy coherence. The development of the OECD Green Growth strategy, which was applied to the case of agriculture, was in part driven by the idea that sustainability and growth could be compatible, and to discuss how this could be feasible (OECD, 2011a and 2011b). The FAO and the CGIAR have encouraged the adoption of climate smart agriculture practice, which combine climate adaptation, mitigation, and production or food security objectives. Recent work at the OECD has looked at synergies and trade-offs at the intersection of productivity, climate adaptation and mitigation (Lankoski, Ignaciuk and Jésus, 2018), and barriers to adoption of climate-friendly agricultural practices (Wreford et al., 2017). Higher-level efforts, such as efforts at the G20 or in the United Nations, particularly with the Sustainable Development Goals, have sought to improve the coherence of a broad set of policy areas.

Yet higher policy plans do not always trickle down to consistent signals to farmers. Existing legislation is not always easy to change, and are not always accounted for in new plans. Local political constraint may make such change difficult. Improved consistency will also not always pass a cost-benefit ratio; it may prevent actions that would enable significant progress towards one objective with a limited cost on the other objective. In extreme cases, it may result in policy immobility: any new policy may be impossible to design if all have to move together.

A pragmatic approach can still be applied on a case-by-case basis. Acknowledging that not all these incoherencies may be practically managed at every stage of the process, governments should focus on major policy inconsistencies or "bottlenecks" (e.g. OECD, 2017c), that significantly prevent progress towards agriculture productivity and sustainability, and set up mechanisms to avoid introducing more inconsistencies.

This requires first to identify and second possibly gauge the importance of policy inconsistencies. The food and agriculture productivity-sustainability framework is ideally set to find out the key inconsistencies, as evidenced in this chapter. Several types of analytical tools can be used to assess the strength of identified incoherencies, such as farm level simulations (Lankoski et al., 2018), sector level models like the Policy Evaluation Model (Henderson and Lankoski, 2019), computational general equilibrium models (see, e.g. OECD, 2017c in the case of the Land-Water-Energy nexus), or *ex post* methods like Fuzzy set Qualitative Comparative Analysis (QCA, see OECD, 2019b). Each of these approaches has advantages and drawbacks, and would benefit from complemented evidence from available literature or other analytical studies.

Governments should then seek to remove identified major policy incoherencies and ensure that new ones are not introduced. Removing incoherencies can take time and may require extensive stakeholder consultations, governance and institutional changes and a well-set plan (e.g. Gruère and Le Boëdec, 2019). Avoiding new inconsistencies will involve more co-ordination, considering agriculture among other objectives at a higher level, ensuring

that policy evaluations are well defined, and introducing coherency principles in agriculture policymaking. This may encompass each new programme passing a coherency test.

Main knowledge gaps

Assessing the cost of major policy incoherencies or benefit of policy coherencies would help raise the awareness of policymakers on the issue. This requires comparing the welfare impacts of alternative scenarios with or without incoherencies, but this has not been done yet consistently, at least in the case of agriculture.

Studies on context-dependent policy incoherencies are lacking. For instance analysing how much to apply the subsidiary principle in agriculture policies, or whether to embed or set independent policies on agriculture and environment (or agriculture and innovation) would be useful.

There have been studies on the political economy of reform, particularly in the case of agriculture or environmentally harmful subsidies, but other such studies on how to address other constraints towards increased coherency would be helpful. For instance, studies on how to remove agriculture policy exemptions that are no longer justified.

Recommendations to minimise policy incoherence

Assess and target the main policy incoherencies.

- Review the main policies to ensure to detect significant policy incoherencies, using the set of tools described above, from the food and agriculture productivity-sustainability framework to more quantitative tools, and looking at the different types of policy incoherencies.
- For identified major inconsistencies, introduce a plan to separate and reduce the misaligned signal from the other parts of the policies (decoupling). This may take time and require extensive stakeholder consultations, changes in governance or institutions, and an accepted reform sequencing.

Ensure that no new incoherencies are introduced

- In the case of innovation, agriculture or environmental policies:
  - Introduce a rapid *ex ante* assessment, with deeper analysis only if needed. An evaluation grid listing the major policy incoherencies could be used at first to detect potential problems, followed by a deeper analysis on a case-by-case basis, using the above-described tools.
  - Review the design of policy evaluations and incorporate the objective of assessing coherence therein. Evaluation should measure the outcome and not just the degree of implementation. The proposed coherence assessment could include a number of elements and ensure that unexpected and unwanted effects on agriculture sustainability or productivity are rapidly mitigated.
- In the case of other relevant policies, encourage lawmakers to open their views on the indirect effects of related policies on agriculture. Ensure that any agriculture exemption does not affect the sector's long-term productivity and sustainability.

Encourage synergistic policy plans, build policy bridges and support win-win policy solutions

- Consider cohesion in high-level policy plans whereby agriculture is not left-out nor special.
- When reviewing agriculture policy and institutional governance, consider bridging out to non-agriculture objectives, including rural development, resource and environment, nutrition goals and encompassing the entire supply chain and not just production.
- Seek solutions that can contribute to productivity and sustainability objectives. In particular, orient the agriculture innovation system towards synergistic solutions for the sector.

Notes

[1] OECD (2019b) finds that the use of cross-compliance mechanisms, which aim to link the two types of regulation, do not appear to have a significant negative impact on productivity in Europe.

[2] Policy customisation is certainly beneficial especially when considering issues that vary widely from one region to the other. However, this heterogeneity may become problematic when it affects the overall productivity and sustainability of agriculture.

[3] Genetically modified herbicide resistant varieties are regulated in Europe, while conventionally bred herbicide resistant varieties, which can lead to similar outcomes, are not subject to similar scrutiny. They are regulated but not under the same regulation.

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Annex A. Some concepts and indicators used in the Framework

As defined by the Oslo Manual (OECD/Eurostat, 2018), **innovation** is a broad concept. It is more than research and development (R&D) and encompasses both the creation and adoption of innovation, which can be "new to the firm, new to the market or new to the world". At farm level, many innovations are "process innovations" as they relate to production techniques, e.g. the adoption of improved seeds or irrigation systems. The downstream industry generates product innovation, such as food with new functional (health) attributes, or non-food products from agriculture for the chemical or pharmaceutical industry (bioeconomy). All along the supply chain, marketing and organisational innovations are increasingly important.

The most comprehensive **productivity** indicator is Total Factor Productivity (TFP), which reflects the efficiency with which firms combine inputs to produce outputs. Partial indicators reflect the efficiency with which the firm uses one input, for example labour or land.

In the framework, **sustainability** refers to the preservation of natural capital in the short and long run, i.e. environmental sustainability. Like physical capital, natural capital needs investment and maintenance to retain its productive capacity in the long run. This encompasses managing agriculture's use of natural resources to ensure their long-term viability and reducing the negative environmental impacts of agriculture production, such as pollutants and waste, which can damage the natural assets. Sustainable agriculture production systems also need to account for the projected impacts of climate change and the associated adaptation responses, as well the mitigation of greenhouse gas (GHG) emissions.

Agri-environmental indicators can help measure sustainability performance of agriculture (OECD, 2018). They can monitor trends in use of land, water and energy, and agriculture's impact on the environment, via the intensity of use of polluting inputs (pesticides) and the sector's emission of pollutants (greenhouse gases, ammonia). They can also provide an assessment of the sector's overall balance of nutrients. Combining these measurements with production-related variables can help decipher the degree of agriculture production decoupling from resource use and environment (OECD, 2014).

Green growth is defined as "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD, 2011).

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Annex B. Overview of reviewed countries

Geographical and economic characteristics

Reviewed countries display a wide diversity of size, geographical location, natural conditions and economic situation. They cover all continents except Africa, and represent a variety of OECD, EU and G20 countries (Table A B.1).

Australia and Canada have the lowest population density (less than four inhabitants per km2 on average but the population is highly concentrated in the most hospitable areas), and higher arable land area per capita (Figure A B.1). This facilitated the development of rather land extensive farming systems, with relatively low impact on the environment, although water availability limits agricultural development in some regions of Australia. In some countries with a more sizeable population, like Turkey, Korea and the People's Republic of China (hereafter "China"), freshwater resources per capita are much smaller than in Australia.

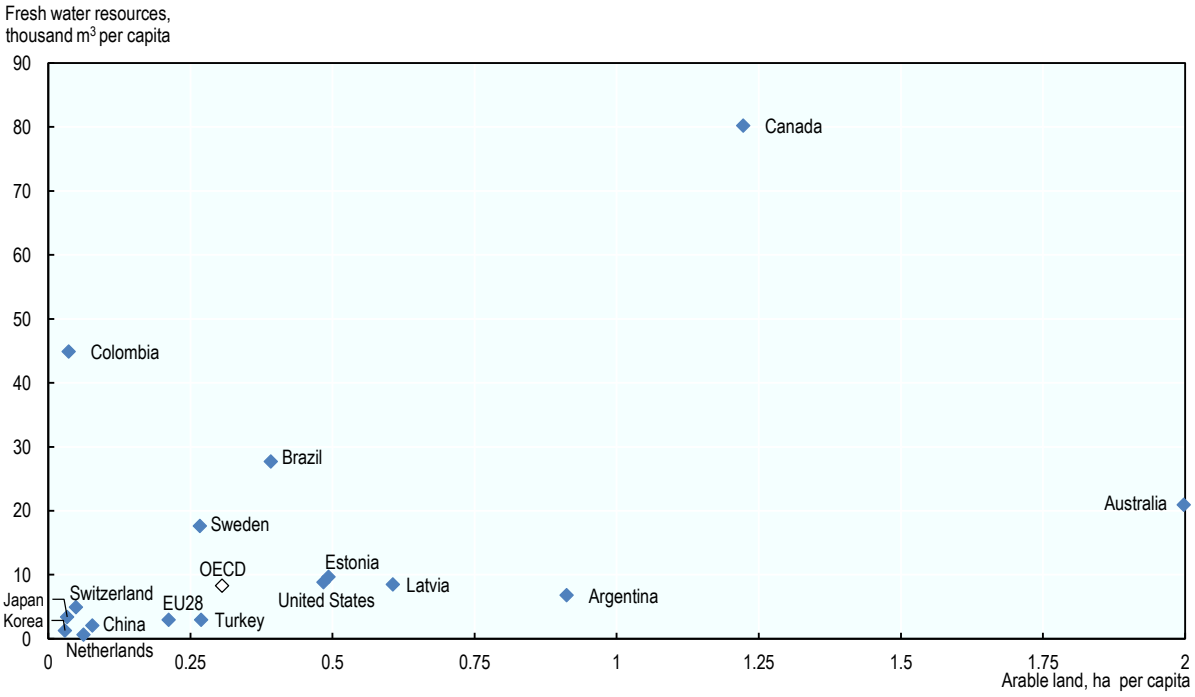
Table A B.1. Some characteristics of reviewed countries, 2017*

Country	Continent	Group	Population (million)	Total land area (thousand km²)	GDP per capita (PPP USD)	Date of publication
			Net exporters of agro-food products			
Argentina	South America	G20	44	2 737	20 787	2019
Australia	Oceania	OECD-G20	25	7 682	50 588	2015
Brazil	South America	G20	209	8 358	15 484	2015
Canada	North America	OECD-G20	37	9 094	46 705	2015
Colombia	South America	G20	49	1 110	14 552	2015
Netherlands	Northern Europe	OECD-EU	17	34	52 799	2015
Turkey	West Asia	OECD-G20	79	770	27 916	2016
United States	North America	OECD-G20	326	9 147	59 535	2016
			Net importers of agro-food products			
China	East Asia	G20	1 386	9 425	16 807	2018
Estonia	Northern Europe	OECD-EU	1	42	31 739	2018
Japan	East Asia	OECD	127	356	43 299	2019
Korea	East Asia	OECD-G20	51	97	38 350	2018
Latvia	Northern Europe	OECD-EU	2	62	27 632	2019
Sweden	Northern Europe	OECD-EU	10	407	50 179	2018
Switzerland	Europe	OECD	8	40	64 835	
Total			2 373	49 369	26 213**	
OECD	All but Africa		1 295	34 466	43 624	
EU28	Europe		512	4 238	41 119	

Note: Agricultural land area data refer to year 2015; ** average of GDP per capita
Source: OECD (2018a), National Accounts (database), https://stats.oecd.org/; FAO (2017), FAOSTAT (database), www.fao.org/faostat/; World Bank (2018), World Development Indicators (database), https://data.worldbank.org/indicator; UN (2018a), World Population Prospects: The 2017 Revision, https://esa.un.org/unpd/wpp/; Eurostat (2017), [demo_pjan], https://ec.europa.eu/eurostat/data/database.

With over 500 inhabitants per km2, population density is the highest in Korea and the Netherlands. As a result, arable land per capita is very limited, and production systems use land intensively. In contrast, countries such as Brazil, Estonia, Latvia and the United States have relatively low population density (less than 40 inhabitants per km2) and high arable land area per capita. In these countries, crop production is relatively extensive, with lower variable input use per ha. This also allows the development of livestock production systems based on grass and own-cultivated feed crops, although non-ruminant production systems based on purchased inputs also exist.

Figure A B.1. Comparing natural resource endowment across countries: land and water, 2014



Source: World Bank (2018), *World Development Indicators*, https://data.worldbank.org.

StatLink https://doi.org/10.1787/888933998861

Food and agricultural structural and trade characteristics

The food and agricultural sectors of the reviewed countries also differ in terms of size and structural characteristics. Primary agriculture accounts for a small share of gross value added (GVA) and employment in most OECD countries (Table A B.2) However, it can be more important in some regions within countries, as outlined in the Australian review. In comparison, agriculture accounts for a larger share of the economy in Turkey, and the two emerging economies reviewed, China and Brazil, in particular when considering its contribution to employment.

Beyond primary agriculture, the whole food and agriculture system has a larger importance for the economy, which is not often measured in official statistics. When the whole supply chain is considered, from input suppliers to agriculture, food processing, wholesaling, and food services, the food system accounts for about 6% of GVA in Canada and the United

States, and over 10% in the Netherlands.[1] The share of the food system in employment is more substantial because food retailing and food services are labour intensive activities. It reached 12% of total Canadian employment in 2012. However, the extent to which the food wholesale, retail and service sectors rely on domestic agricultural production varies by country and sub-sector. For example in the Netherlands, just over half of the activities of the food system are to a greater or lesser extent directly related to domestic agricultural and horticultural production, and they account for about 15% of the GVA and employment of the whole food system.

Table A B.2. Importance of agriculture in the economy, 2016 or latest available year

Agriculture as a percentage of total

	Gross Value Added[1]	Employment[2]	Exports[3]	Imports[3]	Total land area[4]	Total water withdrawals[4]
Australia	3.0	2.6	16.7	6.7	52.8	65.7
Brazil	5.0	13.9	38.5	7.4	33.0	60.0
Canada	1.5	1.9	12.0	8.5	7.2	12.2
China	8.9	27.8	2.5	6.6	54.8	64.6
Estonia	2.6	3.8	9.0	9.5	22.6	0.2
Korea	2.2	4.9	1.2	5.9	18.4	54.7
Latvia	3.9	7.9	17.1	13.7	29.6	12.7
Netherlands	1.8	2.0	17.9	12.8	54.6	1.1
Sweden	1.3	1.6	4.0	8.3	7.5	3.6
Switzerland	0.7	3.1	3.0	4.3	38.6	10.1
Turkey	7.0	19.5	11.0	6.3	49.9	73.8
United States	1.1	1.6	11.3	5.6	44.7	40.2
EU28	1.3	4.3	7.3	6.6	43.0	19.2
OECD	1.9	4.8	16.7	6.7	39.5	30.6

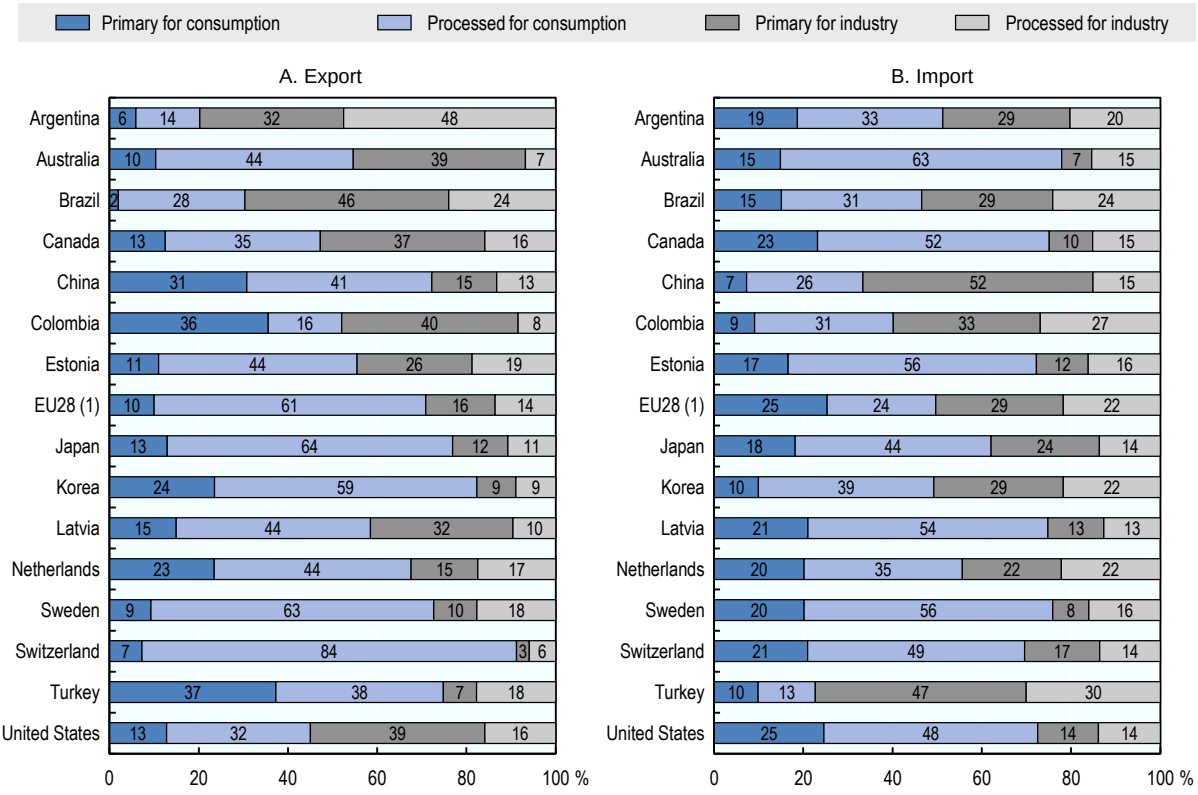
1. 2014 for Brazil, Canada and OECD average; 2015 for the United States. 2. 2015 for Brazil, Latvia and OECD average. 3. 2015 for Estonia, Latvia, Netherlands, Sweden. 4. 2013 or 2014.
Source: OECD (2018b), *Agricultural Policy Monitoring and Evaluation*, using OECD, FAO and WB databases, https://dx.doi.org/10.1787/22217371 .

Reviewed countries also cover a large range of agro-food trade situations: initially tested on large, competitive exporters of agricultural commodities, the Framework has subsequently been applied to both net exporters and importers of agri-food products (Table A B.1). Among net exporters of agro-food products, Brazil is the country where agro-food products account for the largest share — above one-third in 2016 — of all exports, followed by the Netherlands (18%) and Australia (15%). The share of agro-food imports is usually higher in smaller or northern countries, which do not produce the large range of products that consumers demand, such as Mediterranean and tropical products, and are part of the EU Common market. For example, while the Dutch agro-food trade balance is positive, agro-food products account for 13% of Dutch imports, reflecting the reliance on imported feed for livestock production, and the importance of domestic agro-food processing industries based on imported products (e.g. coffee and cocoa).

In large exporters of agro-food products, primary products for industry often account for a large share of agro-food exports, reflecting the competitiveness of their agriculture (Figure A B.2). A high share of primary products for consumption in exports often reflects fruits and vegetable specialisation as in Colombia, Turkey and China. A number of European and Asian countries that are net importers of agro-food products have a high

share of processed products for consumption in their agro-food exports, indicating they are specialised in high value products, which can be based on imported agricultural products.

Figure A B.2. Composition of agro-food trade, 2016



Notes: Numbers may not add up to 100 due to rounding. Agro-food definition does not include fish and fish products. Agro-food codes in H0: 01, 02, 04 to 24 (excluding 1504, 1603, 1604 and 1605), 3301, 3501 to 3505, 4101 to 4103, 4301, 5001 to 5003, 5101 to 5103, 5201 to 5203, 5301, 5302, 290543/44, 380910, 382360.
1. Extra-EU trade.
Source: UN (2018b), ComTrade Database, https://comtrade.un.org/ (accessed August 2018).

StatLink https://doi.org/10.1787/888933998880

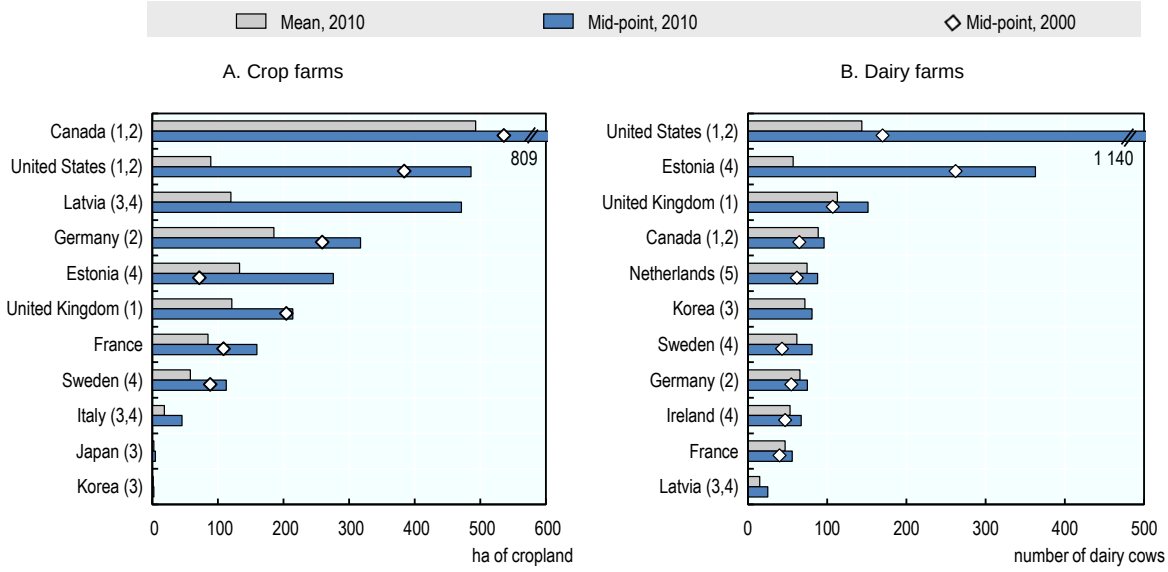
Within and across countries, land ownership, farm size and production systems vary widely. Family farms dominate in most countries, although they can be very large, with a complex management and ownership structure, for example in the United States. Large corporate farms are relatively more frequent in the Estonia dairy sector and Latvian crop sector. Farm size varies by region and type of production. For example, in China, Japan and Korea average crop farm size is less than 2 ha, while it reaches about 500 ha in Canada (Figure A B.3).

In many countries, technological advances and increased labour productivity growth have enabled farms to increase scale of operations and consolidate. Farm consolidation has occurred at a fast pace in some countries but remains slow in others. As a result, there are large differences in farm size distribution (Figure A B.3). For crop farms, the mid-point farm size, which is the median of the distribution of land (or production, or livestock numbers) by farm size, increased significantly in the 2000s in all countries for which data

are available. In 2010, it ranged from less than 5 ha in Japan and Korea to over 800 ha in Canada, where the size increase has been particularly large.

The growth in dairy farm size, as measured by the number of animals, in the 2000s has been particularly spectacular in the United States, where the mid-point farm size reached 1 140 dairy cows per farm. Significant growth also occurred in many EU Member States, where former EU dairy production quotas were managed flexibly. In Canada, growth in dairy farm size is also significant but not as large as that in crop farms, or in US dairy farms. Despite consolidation, most countries have a wide diversity of farms, in terms of size and production systems. The persistence of smaller farms is observed in countries with no obstacles to structural adjustment, such as the United States,[2] and in this case may reflect alternative choices of lifestyle (hobby, part-time) or strategy. As with other structural characteristics, farm size may affect productivity and environmental sustainability performance, as discussed below.

Figure A B.3. Mean and midpoint farm size, 2000 and 2010



Notes: Panel A: The mid-point farm size applied to crop farms is the hectare-weighted median, which corresponds to a farm size that separates the farm size distribution into two parts: 50% of the total area of the national farmland operated by the crop farms of a larger size and the other 50% by the crop farms of smaller size than the hectare-weighted median. Panel B: The mid-point statistics used to measure the distribution of dairy farm size is the livestock unit-weighted median.

1. 2010 is replaced by the nearest available year: by 2009 for the United Kingdom (England), by 2011 for Canada, and by 2012 for the United States.
2. 2000 is replaced by the nearest available year: by 1997 for the United States, by 2001 for Canada, and by 2003 for Germany.
3. Mid-point 2000 data are not available for Italy, Japan, Latvia and Korea (crop farms); and for Korea and Latvia (dairy farms).
4. Based on sample data. For Latvia and Estonia, it excludes farms with a Standard Output less than EUR 4 000, that is 64% of Latvian farms.
5. For the Netherlands, data are on all farms having cropland, dairy cows and pigs, respectively.

Sources: Bokusheva and Kimura (2016), "Cross-Country Comparison of Farm Size Distribution", Tables B3 and B4, https://dx.doi.org/10.1787/5jlv81sclr35-en; OECD (2018c), *Innovation, Agricultural Productivity and Sustainability in Korea*, https://doi.org/10.1787/9789264307773-en.

StatLink https://doi.org/10.1787/888933998899

The agri-food industry also includes a diversity of firms. Structural characteristics of input suppliers and food processing industries also affect the productivity performance of the whole system. Technological, product and marketing innovations are essential to maintain competitiveness along the food chain. In most reviewed countries, open markets facilitate access to good quality inputs and innovative technologies. High and increasing concentration in seed or farm machinery sectors has raised some concerns, although competition authorities have ensured sufficient competition to limit market power. Diverse and competitive food processing companies contributed to agro-food production and export growth in the United States and the Netherlands. However, in other countries like Canada and Estonia, the small scale of food processing companies limits their ability to take further advantage of export markets. Large multinational companies dominate global markets, but they tend to invest in countries with a large market size. In most countries, the retail sector is characterised by high concentration, but alternative channels, such as short supply chains, remain and even develop.

Agro-environmental performance

Table A B.3. Trends in agriculture's resource use and selected environmental impacts in reviewed countries, 1990-92 to 2013-15

Increases are shown in bold

	Changes in resource use			Changes in environmental impacts		
	Agriculture freshwater abstraction	Total agriculture land area	Total final energy consumption	Total sales in agriculture pesticides	Ammonia emissions	Total GHG emissions from agriculture
Argentina		**17%**	**95%**	**649%**		-18%
Australia	-31%	-15%	**44%**	**152%**		-9%
Brazil	**88%**	**16%**	**103%**	**537%**		**43%**
Canada	-50%	-4%	**24%**		**21%**	**20%**
China		**3%**	**177%**	**131%**		**55%**
Colombia		0%	**33%**	**261%**		-1%
Estonia	-86%	-29%	-41%		-46%	-46%
Japan	-8%	-16%	**2%**	-40%		-8%
Korea	**18%**	-20%	**132%**	-27%	**167%**	-2%
Latvia	-17%	-25%	-35%		-57%	-44%
Netherlands	-45%	-7%	**15%**		-63%	-27%
Sweden	-42%	-10%	-2%		-5%	-6%
Switzerland		-5%	**3%**		-14%	-9%
Turkey	**153%**	-5%	**109%**	-23%	**114%**	**26%**
United States	-10%	-4%	**17%**	**15%**	-8%	**4%**

Notes: Australia: 1994 and 2009-2011 for agriculture freshwater abstraction; Brazil: 2001-2003 and 2010-2012 instead of 1990-92 and 2013-15 for agriculture freshwater abstraction, 2010-2012 average instead of 2013-15 for GHG emissions; China: data for China Mainland for pesticide sales, use of1994 instead of 1990-92 and 2012 instead of 2013-15 for GHG emissions; Estonia and Latvia: 2000-2002 average instead of 1990-92 for agriculture freshwater abstraction; Turkey: 2000-2002 average instead of 1990-92 for pesticide sales; Korea: 1999-2001 average instead of 1990-92 for ammonia; Netherlands: 2010-12 average instead of 2013-2015 for agriculture freshwater abstraction; Sweden: 2010 instead of 2013-15 for agriculture freshwater abstractions; Switzerland: 2012 instead of 2013-15 for agriculture freshwater abstraction; United States: 2010 instead of 2013-15 for water withdrawals.

Source: OECD (2018d), OECD agri-environmental indicators, www.oecd.org/tad/sustainable-agriculture/agri-environmentalindicators.htm (accessed in April 2018); FAOSTAT (accessed in September 2018) for agriculture land and pesticide sales in Argentina, Brazil, Colombia and China.

Notes

[1] The share of the agri-food complex in total gross value added was 8% in 2015, www.agrimatie.nl/ThemaResultaat.aspx?subpubID=2232&themaID=2280&indicatorID=2919&sectorID=2243.

[2] This is also linked to US farms being broadly defined as any place from which USD 1 000 or more of agricultural products were produced and sold, or normally would have been sold, during the year.

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Annex C. Country notes

Each note refers to the national assessment and recommendation at the time each country review was published (year indicated on the top of each country note). Efforts undertaken since the review publication are not accounted for.

Australia (2015)

Box A C.1. Main opportunities and challenges for the food and agriculture system in Australia

- Australia has abundant agricultural land, but agricultural productive potential is constrained by poor soils, scarce water resources and the most variable climate conditions in the world.
- The agricultural sector has a strong export focus, and many sectors are heavily reliant on foreign markets as the primary source of their demand.
- Productivity growth has been central to the continued viability and competitiveness of Australian farm businesses, and driven by advances in technologies and structural adjustment on the back of continued reforms.
- Productivity growth in agriculture slowed down considerably in the 2000s, due, in part, to the difficult climatic conditions that prevailed throughout this period.
- Low water availability in Australia's agricultural producing regions, which climate change will accentuate, is a principal factor limiting the expansion of agricultural activities.
- Australia's agriculture and food industries are well-placed to exploit global food demand, but this depends on maintaining productivity growth relative to trade competitors.

Table A C.1. Policies for improving food and agriculture productivity and sustainability in Australia

Main findings	Key recommendations
Incentives for private investment	
Australia's overall policy framework supports innovation, but the regulatory burden on farmers could be reduced through increasing regulatory coherence across jurisdictions.	Continue efforts to improve the coherence of regulations nationally that affect agro-food businesses. Continue to improve the functioning of water markets, including through harmonising water access rights across jurisdictions, enhancing the co-ordination of the system, and performance assessment.
Eliminating and reducing unnecessary impediments to financing investment in innovation	Explore the nature of perceived difficulties in accessing finance for innovating farm businesses. Work with capital provides to identify areas where information to assess risks involved in financing new agri-business activities and technologies could be improved. Raise the awareness of farm and agro-food investors about options for non-bank financing. Investigate the demand for, and supply of, venture capital for agro-food industries, particularly for value chain development projects; identify constraints to this type of financing and any possible government role to ease these constraints.
Capacities and services	
Reducing infrastructure bottlenecks remains a challenge	Pursue improvements in infrastructure outcomes through more effective planning and by reducing the complexity of infrastructure governance. Assist potential investors build a better vision of future infrastructure needs. Undertake a comprehensive assessment of future agro-food infrastructure needs, considering: possible climate-related shifts in production patterns, value chain development prospects and environmental targets. Evaluate the long-term impact of public support to modernise irrigation infrastructure on water use in agriculture.
There are uncertainties about the future supply of labour and skills for agriculture	Undertake a national survey of agriculture and food industries to diagnose current and potential skills bottlenecks. Explore arrangements to better match demand and supply of skills in the agriculture and agro-food industries. Explore the scope for job placement programmes and immigration schemes that target agro-food industries and orient these to longer-term labour and skills needs beyond current seasonal labour schemes.

Main findings	Key recommendations
Skills require a push towards top levels of international performance and need to be more strongly guided by industry demand	In the context of fiscal consolidation and education reforms, maintain the commitment to 2020 education attainment targets. Consider a nationally-scoped and co-ordinated campaign to promote agro-food careers that emphasises the opportunities for high-skilled and knowledge-intensive jobs.
Agricultural policy	
Agricultural policy focuses on the sector's long-term development needs. Keeping the focus of drought policy on farmer preparedness and adaptation will facilitate innovation	Keep the commitment to focus on measures to improve the preparedness of farmers and their adaptation to climate change. Investigate the link between increased climate risks and the willingness of Australian farmers to invest. Explore the possible impacts of various drought measures on farmers' risk perceptions and innovation activity.
The effects of taxation in agriculture require better understanding	Assess the impact of tax reforms on productivity, structural change and sustainable resource use.
Direct incentives to innovation	
The rural innovation system is responsive to short-term primary industry demand, but also needs to address broader long-term challenges	Provide a long-term vision for investment in the agricultural innovation system when revising government priorities and reviewing funding mechanisms. Maintain the focus on climate change as a key factor for the future competitiveness of Australian agriculture.
Governance mechanisms ensure the coherence of a complex and interactive system, and facilitate continuous policy adaptation	Implement and, if needed, adapt the National Primary Industries Research, Development and Extension (RD&E) Framework to support greater collaboration and co-operation. Adapt Research and Development Corporations (RDCs) to improve their responsiveness to cross-commodity issues, e.g. by creating a cross-sector thematic RDC, or by broadening the mandate and partnership of existing ones.
Growth in public funding of rural R&D has slowed, while demand for innovation has broadened and longer term challenges receive increasing public attention	Consider public funding for innovation, R&D and extension activities not covered by existing supply chains Provide stable support to knowledge infrastructure and long-term projects, to strengthen the capacity for collaboration at the international level and to allow for break-through innovations.
Agribusiness underinvests in rural R&D despite estimated large returns on investment	Enhance the involvement of processing industries and retailers in innovation, by making them an integral part of the system, from the priority setting stage to the financing and commercialisation of innovation stage.
Stronger international R&D co-operation would benefit the sector and society	Explore further opportunities for bilateral and multilateral co-operation in R&D and technology transfer.
Further productivity gains require wider diffusion of innovation across farms and will depend on the capacity of the system to respond to a changing and more diverse sector	Use farm surveys to generate data on innovation (as was done once about ten years ago) in order to analyse the characteristics of innovators and the main barriers to adoption on farm. Review technical assistance and the extension system to ensure adequate public and private supply and access by all farmers.

Source: OECD (2015a), *Innovation, Agricultural Productivity and Sustainability in Australia*, https://dx.doi.org/10.1787/9789264238367-en.

Brazil (2016)

Box A C.2. Main opportunities and challenges for the food and agriculture system in Brazil

- Brazil is the world's fifth largest country, both by land area and population.
- Agriculture benefits from abundant land and water resources, and diverse geographical conditions, although most of the country is tropical.
- Agriculture and the agro-processing sector have shown impressive growth, largely driven by productivity improvements and structural adjustment resulting from broad economic reforms, as well as new technologies.
- Sustaining high agricultural growth is critical to Brazil's overall development given the importance of the agri-food sector to the national economy and to poverty reduction
- It is also important globally due to Brazil's role as a leading supplier on international agricultural markets.
- Key drivers of agricultural growth in the past have weakened, necessitating increased cost-competitiveness.
- Main challenges are to ensure that the sector expands sustainably; to reconcile agricultural growth with poverty alleviation objectives; and to overcome structural deficiencies characteristic of an emerging economy.

Table A C.2. Policies for improving food and agriculture productivity and sustainability in Brazil

Main findings	Key recommendations
Incentives for private investment	
Businesses face fairly restrictive and complex regulations, and incur high costs for doing business	Reduce overall regulatory burden on entrepreneurship, particularly, by simplifying regulatory procedures and easing administrative burdens on start-ups. Undertake a comprehensive review of regulations that govern agriculture and agro-industries to identify areas where the burden of these regulations could be reduced, such as stronger coherence of regulations across regulatory areas and different administrative levels.
Tariff protection for capital and intermediate goods is high, increasing the cost of agricultural inputs	Reduce industrial tariff protection to lower the cost of imported inputs and technological items, including for the agricultural and agro-processing sectors.
Domestic credit is generally costly and difficult to access, while long-term credit is scarce	Facilitate the development of private long-term finance, including, as an interim approach, by requiring private co-financing of loans from the National Bank for Economic and Social Development (BNDES). In the longer-term, phase-out financial support to BNDES and concentrate its lending on infrastructure, small and medium-sized enterprises, and on innovation.
Businesses bear a substantial tax burden and high costs to comply with tax regulations	Simplify the tax system, in particular, by further efforts to unify indirect taxes into a single national system.
Capacities and services	
Agriculture is set to gain substantially from infrastructure improvements	Sustain the commitment to accelerated development of infrastructure and move forward planned infrastructure projects; reduce investment delays and increase private investment in infrastructure through further simplification of regulatory procedures.
Labour regulation framework requires modernisation	Modernise labour regulations to allow for greater flexibility in labour agreements and to reduce uncertainties in the interpretation and application of regulations. Enhance labour market insertion programmes with a greater focus on training and re-training of job seekers.

Main findings	Key recommendations
Education improvements have been impressive but there is much scope for further catch up	Ensure that improvement in education quality is on par with a wider access to it, and support the advancement of poor students, particularly from rural areas, to higher levels of education and performance. Continue to develop the agricultural vocational training system and facilitate greater use of apprenticeships to enhance agricultural skills. Promote co-operation between agri-business and educators in the development of curricula and their adjustment to business demands. Encourage arrangements for industry-public co-funding of training and job placement programmes.
Agricultural policy	.
Agricultural policy serves two distinct farm segments and is driven by different rationales. It has been liberalised and increasingly incorporates sustainability criteria, but it can be more strongly oriented to productivity and sustainability outcomes	Move away from interventions that lower producer current costs and eliminate cross-commodity variations in support levels as a broad policy re-orientation.
Refocussing credit support to well-specified investments could spur innovation resulting in productivity and sustainability improvements	Reform the concessional credit system with the view to gradually limiting the scope of eligible commercial producers and their supported activities. Further promote the development of private non-bank financial instruments for agriculture and agro-industries, subject to a review of existing instruments. Pursue efforts to ease access to credit by rural borrowers though simpler regulations and procedures. Assess concessional investment credit with the view to streamlining existing programmes and simplifying access procedures. Enhance criteria for loan eligibility to better screen out borrowers that would have invested without support. Increasingly shift concessional investment credit to projects that explicitly incorporate technological innovations, and advanced farm management and environmental practices. Maintain the focus of concessional investment credit on farm infrastructure support, subject to performance assessment of new infrastructure credit programmes.
Direct incentives to innovation	
The agricultural innovation system is an effective provider of innovation: it benefits from well-established governance mechanisms; as a sector-specific organisation, the Brazilian Corporation for Agricultural Research (Embrapa) plays a central role in the system, while universities contribute with high quality education and research; Foreign R&D co-operation is developing fast. However, there is scope for further developing collaboration with other research partners.	Promote research co-operation across sectors (Centres of Competitiveness or Excellence). Strengthen Embrapa's capacity and flexibility to collaborate with other researchers in universities and the private sector in Brazil and abroad, for example by removing restrictions for public institutions to hire foreign researchers and trainees, facilitating temporary transfers of Brazilian researchers abroad, and exploring arrangements regarding the sharing of property rights.
The contribution of agribusiness should continue to increase as there is still unrealised potential for contributions by the private sector in agricultural innovation due to the general business environment and lack of capacity of local companies to do this	Consider strengthening Intellectual Property Right protection to attract private investment. Strengthen the capacity of businesses to participate in local innovation projects by supporting networking and actions to raise awareness and providing training opportunities.
Adoption could be faster and more widespread.	Reinforce technical assistance and rural extension services to ensure they provide expected services and improve opportunities for small family farms. Broaden the scope of advisory services to cover technical, financial and organisational aspects. Strengthen links between R&D and technical assistance, for example by adding a technology transfer component to research projects, or by encouraging networking between researchers, advisors and producers.

Source: OECD (2015b), *Innovation, Agricultural Productivity and Sustainability in Brazil*, https://dx.doi.org/10.1787/9789264237056-en.

Canada (2015)

Box A C.3. Main opportunities and challenges for the food and agriculture system in Canada

- Canada is a very large country in terms of land mass, occupying the Northern part of America, with a relatively small, wealthy and open economy.
- Canadian agriculture benefits from relatively abundant land and water resources, although there are significant regional differences in environmental pressure and climate, and it faces limited environmental constraints which relate mainly to local water pollution by agricultural nutrients.
- Canada is a major and competitive exporter of agricultural commodities.
- Agricultural productivity growth, resulting from technological advances and increases in farm scale and consolidation, has driven production and income growth without significantly increasing pressure on resource use.
- The capacity to innovate is crucial for the export oriented Canadian sector to take advantage of the growing and changing demand for food and agricultural products at the global level.

Table A C.3. Policies for improving food and agriculture productivity and sustainability in Canada

Main findings	Key recommendations
Incentives for private investment	
Efforts are being made at the federal and provincial levels to reduce regulatory burden without compromising health and environmental safety outcomes.	These efforts should continue by improving clarity, consistency and responsiveness to industry and consumer needs, using more outcome-based regulations, and adopting a forward-looking approach to developing regulations for new products and services. Regulatory services to businesses should be strengthened. To reduce compliance costs, information relevant to companies could be included in a single platform. Further efforts could focus on regulatory collaboration between provinces and with main trade partners.
Farmers and food industries have access to credit and specialised and personalised services from a well-developed financial and banking sector. In addition, they benefit from specific agricultural credit programmes.	The extent to which agriculture credit programmes are well targeted and respond to the current credit market situation should be reassessed.
Various programmes support investment and innovation. The government has also taken steps to support the development of venture capital markets.	Efficient and deep financial markets should continue to be promoted. In addition, placing information on market and programme opportunities on a single platform would improve access to capital.
Lower rates of corporate tax for small firms may act as a disincentive to firm innovation and growth.	Applying the same rate to all firms would remove this disincentive.
Capacities and services	
There is a mismatch between supply and demand of skills for innovation in agriculture.	Skills for innovation could be reinforced by increasing integration between education, formal training and practical experience within tertiary education, increasing the distinction between institutions that target research and those that emphasise teaching, and re-evaluating tuition policies. Increased efforts should be made, in particular by the private sector, to better communicate evolving needs to educators and to promote further opportunities, such as internships, which are responsive to evolving business needs.
Shortage of labour is a growing issue.	Further efforts could be made to enhance the public's perception of agriculture and its role in the economy, including by improving information on job market opportunities in the sector.
Agricultural policy	.
High levels of support through domestic and border measures like those in place for supply-managed commodities distort markets and can impose a high cost on intermediate and final consumers.	Lowering support and minimising distortions could help the industry adapt to market opportunities, including through enhanced innovation.
The dairy, poultry and egg sectors operate under a supply management system. This discourages structural adjustment, which is an important driver of productivity growth, together with innovation.	Removing impediments and/or disincentives to structural adjustment could facilitate the adoption of innovation and increase productivity growth.

Main findings	Key recommendations
Canadian agricultural policy traditionally provides farmers with tools and support to manage risk and facilitate investment. Innovation has received more attention in the most recent Growing Forward 2 policy framework.	Programmes that target innovation directly and provide incentives for private investment in the creation and adoption of innovation should be further developed.
Direct incentives to innovation	
Agricultural innovation includes a large diversity of actors, which calls for strong co-operation and governance systems. Economy-wide, agriculture and innovation policy provide incentives to innovation.	Establish a common strategy for agriculture and broader, government-wide innovation objectives to strengthen policy coherence.
Innovation policies are regularly evaluated according to the common framework used to evaluate all government policies, and which is mainly based on trends in economic performance.	Evaluate all agricultural programmes in terms of their impact on innovation, as the results would help to strengthen the focus on innovation of future frameworks. The development of outcome and performance indicators needs to be built into the policy-making process and used to evaluate policy impacts to allow for future improvements.
The public sector is the main supplier and funder of agricultural R&D through various institutions and programmes.	Simplifying programming, such as initiatives related to financial support and business management advice, that aim to facilitate the adoption of innovation in farms and firms, would improve access to support and information, and thus to innovation. There should be a single platform which can identify all sources of available government funding. Streamlining fragmented federal granting programmes would encourage businesses to collaborate with researchers in the public sector. It would also help if provinces aligned their grants with those of the federal government.
Knowledge infrastructures, such as research centres and universities, are well-spread across Canada and tend to specialise into regional systems. However, these infrastructures are ageing.	To maintain research capacity, ensure stable funding for knowledge infrastructure, including general knowledge technologies, institutions, networks and databanks, as well as funding for long-term projects
Public research expenditures are relatively high but decreasing in real terms. Private investment in agricultural R&D is increasing, but in general, there appears to be scope for an expanded private sector role.	Explore funding models that can help attract private sector investment, as well as public private partnerships that can support agricultural knowledge infrastructure and further innovation.
Because of the diversity of actors and stakeholders in the Canadian agricultural innovation system, consultation and co-ordination mechanisms are in place, and collaboration is encouraged.	Review the effectiveness of co-ordination and the responsiveness of the system to stakeholder demands. To increase collaboration and partnerships between public and private actors it is important to explore and tackle difficulties such as differences in culture, constraining requirements for using public funds, and frictions over the handling of Intellectual Property Rights (IPRs).
At the time of the review, Plant variety protection in Canada was lower than in many developed countries, as Canada had not sign the more protective 1991 UPOV convention.	Strengthening Plant Breeders' Rights would attract private investment and place Canadian farmers at a level playing field with their major competitors on world markets.
So far venture capital benefits mainly Information and Communications Technology (ICT) companies, and only a few agri-food companies have been successful at accessing it.	Further investigate the demand and supply for venture capital for agricultural businesses and identify constraints and possible government role to ease these constraints.
The government plays an important role in facilitating flow and access to information.	It must also contribute to improving public understanding of the importance of innovation in the agricultural sector, as well as to society at large.

Source: OECD (2015c), *Innovation, Agricultural Productivity and Sustainability in Canada*, https://dx.doi.org/10.1787/9789264238541-en.

China (2018)

Box A C.4. Main opportunities and challenges for the food and agriculture system in the People's Republic of China (hereafter "China")

- China achieved a remarkable expansion of agricultural production, but intensive use of chemical inputs has led to soil degradation, water pollution, and damaged bio-diversity.
- Water resources reached the limit of sustainable use, particularly in areas where irrigation is intensive or water resources are scarce. The development of the intensive livestock sector has created serious environmental stress, especially on water quality.
- China has succeeded in reducing the incidence of poverty in rural areas, but rapid industrialisation has led to large income disparity between urban and rural households.
- The rising cost of labour and the rapid aging of the rural population require agricultural production to concentrate on a smaller number of more productive farms.
- Consolidating small and fragmented farm operations in large-scale units is one of the most important pathways of improving productivity growth and sustainability in China.
- Dietary changes associated with income growth have been a major driver for the shift of domestic agricultural production towards livestock and fruits and vegetables.
- Future growth opportunities of agriculture in China lie primarily in agricultural products that are intensive in capital and knowledge.

Table A C.4. Policies for improving food and agriculture productivity and sustainability in China

Main findings	Key recommendations
Incentives for private investment	
The quality of governance is still lower than the OECD average, most notably in the protection of property rights, both physical and intellectual.	Strengthen the enforcement of intellectual property rights by raising awareness of laws and increasing penalties for infringements and systematically prosecuting violators.
The State Owned Enterprises (SOEs) are dominating some areas of the service sector (e.g. financial services).	Reduce barriers to entry and investment into services related to food and agriculture sector to enhance value addition.
Capacities and services	
Ensuring long-term stability of land contracts and operational rights is also important to provide incentives to commit to long-term investments in land.	Secure long-term stability of contracts and operational rights of land by: increasing the duration of contracts and operational rights, with contracts automatically renewable upon expiration; establishing a registration system of operational rights at the local level; providing certificates detailing land rights.
Sustainable agriculture productivity growth requires a sufficient and stable quantity of usable freshwater for crops and livestock, and minimised impacts of agricultural activities on water resources.	Conduct a comprehensive review of water governance to better define responsibilities, remove conflicts and ensure effective and efficient policy implementation. Implement the proposed 2016 water price mechanism. Enforce the three red-line policies on water resource efficiency, conservation and water quality with enhanced monitoring and evaluation. Prioritise policy efforts to agricultural regions concentrating the most water risks.
China's household registration (hukou) system restricts access to social security and education systems in urban areas for households registered in rural areas	Ensure more equal access to social and education service in urban areas to facilitate the migration of rural residents to urban areas.
The education attainment of rural residents is largely limited to lower-secondary level and not necessary skill-based.	Increase vocational training opportunities and develop the broad skill sets needed to adapt and innovate in the agriculture sector; facilitate life-long learning and upgrading of skills in agriculture.
Agricultural policy	
More integration with international markets and decoupling of support from production would optimise the domestic agricultural structure and reduce pressure on the environment and national resources.	Further decouple the existing commodity-specific support from production to enhance reallocation of resources based on market demand and to allow producers to set aside farmland, while maintaining production capacity.

Main findings	Key recommendations
The continued pursuit of food grain self-sufficiency is becoming more costly in terms of both maintaining a large amount of public stock of grains and unsustainable use of land and water resources	Following the reform to reduce or cap the minimum purchase prices for rice and wheat, consider in the future replacing domestic price support policy with direct payments for rice and wheat, making domestic prices close to international prices.
Existing agricultural policy instruments to promote grain production are not necessarily coherent such agri-environmental policy objectives.	Review existing agricultural policy to improve their coherence with agri-environmental policy objectives including the removal of all the implicit support to fertiliser and chemicals.
The effective enforcement of environmental regulations remains a major challenge. Further monitoring and liability management will be necessary to make progress, but this is costly under China's small and fragmented agricultural structure.	Strengthen the enforcement of environmental regulations through strengthening monitoring and liability management as well as complementary measures such as making payments conditional on the recipient's compliance with environmental standards adapted to local conditions.
Subsidy to purchase agricultural machinery stimulated the replacement of inefficient smaller machines with more efficient larger ones. However, this subsidy should only have a transitory role.	Scale down the subsidy to purchase farm machinery, while increasing the role of rural credit institutions in financing farm capital investment.
Direct incentives to innovation	
Agriculture R&D activities are dominated by public agricultural R&D institutions, and private agriculture R&D expenditure is estimated to account for only 10-20% of overall agriculture R&D. The role of private agriculture R&D is lower than in most OECD countries.	Focus public agricultural R&D on areas of public interest such as environment and resource conservation and on areas where the private sector would under-invest and privatise the public R&D institutions in commercially viable areas of research.
China's protection of IPR still lags behind most OECD countries, particularly in the area of enforcement. China maintains barriers to Foreign Direct Investment (FDI) in agricultural R&D. For example, foreign companies are not allowed to conduct research on transgenic crop breeding.	Strengthen the role of the private sector in agricultural R&D through more effective enforcement of IPR protection, more transparent biosafety regulation, lower barriers to FDI in agricultural R&D.
China's agricultural innovation system can be characterised as a top-down one, where scientists in the public sector create new technologies with little consideration of farmers' changing demands.	Improve co-ordination between government agencies and public research institutes at national and subnational levels to avoid duplication, and increase the linkage between public research institutions, higher education institutions, agri-food enterprises, and public and private extension services to reflect industries' changing demands to public agricultural R&D activities.
The commercialisation of extension activities reduced their capacity to provide a variety of technical advice. Private organisations are increasingly playing a major role in facilitating knowledge flows.	Concentrate the role of the public extension system to the services which private organisations have less incentive to provide, such as promoting sustainable production practices.

Source: OECD (2018a), *Innovation, Agricultural Productivity and Sustainability in China*, https://doi.org/10.1787/9789264085299-en.

Estonia (2018)

Box A C.5. Main opportunities and challenges for the food and agriculture system in Estonia

- Estonia is the northernmost and smallest of the Baltic countries.
- Estonia has experienced significant structural change and growth in agricultural production and productivity, in particular since the country joined the European Union in 2004.
- This growth was achieved with relatively limited, mainly localised, environmental pressure, taking advantage of abundant land and water resources.
- Most productivity improvements occurred in larger farms, and there is scope for increasing productivity in smaller farms.
- The food processing sector has not invested as much and adjusted as fast as primary agriculture, and is still struggling in terms of capacity and competitiveness.
- Looking forward, the agri-food sector will have to keep adjusting to changing conditions, such as higher labour costs, agricultural policy developments, more diverse demand, and climate change, which will provide both opportunities and challenges.
- Responding to demand for diversified, healthier products can be an opportunity to develop new products, and improve the competitiveness of the Estonian agro-food sector.
- Maintaining the recent growth rates sustainably will require further innovation and adaptation in food and agriculture.

Table A C.5. Policies for improving food and agriculture productivity and sustainability in Estonia

Main findings	Key recommendations
Incentives for private investment	
Access to traditional export markets has been disrupted by the Russian ban on imports.	Promote a regional approach to trade diversification in order to gain new markets for agri-food products.
Agricultural loans have a higher risk premium on markets.	Promote risk management, through financial tools.
High taxes on labour increase labour cost.	Further reduce the taxation of labour earnings to facilitate employment in food and agriculture.
Environmental taxes and charges have increased, but do not always reflect environmental damages. Fuel used in agriculture is taxed at 27% of the standard rate.	Explore the scope for using environmental and agri-environmental taxes. Reduce gradually the tax rebate for fuel used in agriculture and encourage the use of renewable energy.
Capacities and services	
Estonia has a good potential for producing biomass from agriculture and forestry.	Develop green energy, and facilitate the development of bio-based products.
The drainage system is upgraded but requires maintenance, all the more with climate change.	Facilitate co-operation among land owners and farmers to improve the maintenance of the drainage system.
Rural areas face a declining population and shortage of skills.	Efforts to attract and maintain people in rural areas could include improving infrastructure connection, and services, providing information on employment opportunities, and facilitating relocation.
The number of Estonian students is declining overall and especially in agriculture and bioeconomy.	Attract foreign students in agriculture-related topics, by offering more courses in foreign languages and adapting them to demand.
Agricultural policy	
Implementation of agricultural policy supported investment to increase productivity and meet EU environmental and other regulations, while limiting market distortions.	Continue to limit distortions and develop support targeting for specific objectives; Promote risk management and strengthen risk management tools; Phase out national complements to Direct Payments.
Despite improvements in environmental performance some local issues remain.	Strengthen efforts by providing targeted advice on sustainable technologies and practices.
COP21 engagements may impose pressure on agriculture to reduce greenhouse gas (GHG) emissions	Explore options for reducing GHG emissions from agriculture, in particular grazing livestock, and facilitate farmers' adaptation and relevant research.
The competitiveness of the agri-food sector remains low.	Develop a competiveness strategy with the sector.

Main findings	Key recommendations
Stakeholders need to develop a strategy for responding to specific market demand (e.g. organic products) and for strengthening technological, organisational, and marketing innovation.	Make use of the opportunity given by the CAP to recognise Producer and Branch Organisations and support the participation of farmers or farmers' organisations in knowledge networks.
Estonia has strong Information and Communication Technologies (ICT).	Develop further ICT solutions to collect and manage data, reduce control costs and implement more targeted policies, and to improve traceability along the food chain. Explore the scope for using output-based agri-environmental measures with the help of ICT for monitoring outcomes.
Direct incentives to innovation	
The abundance of strategic documents, action plans, programmes and projects does not facilitate coherence.	Consolidate innovation and growth strategy documents to improve clarity.
The policy framework is driven by supply-side measures, with relatively little input from, or ownership by, the business community.	Better involve the private actors in policy dialogue on R&D and innovation policies at an early stage.
The approach to innovation is top-down.	Facilitate discussion among and between producers and the industry to enable them to contribute more effectively and efficiently to the agricultural innovation system.
The funding of R&D for agriculture fluctuates across programming periods and is highly dependent on short-term projects.	Improve the stability of R&D funding; Continue developing longer-term, larger scope project funding.
Explore ways to complement public funding, for example from foundations or agricultural levies.	
Maintaining good research infrastructure is essential for future progress and to maintain excellence and collaboration capacity at national and international levels.	Maintain and improve research infrastructure, including EU and regional networks. Explore further opportunities to share public infrastructure with the private sector.
The contribution of private companies to research is limited, in particular in the food and agricultural sector.	Identify areas where local companies and researchers could collaborate, e.g. through public-private partnerships, to develop local or niche products and innovation.
Skills for innovation in the system need to be upgraded continuously.	Encourage a diverse supply of advice that is accessible, including through ICT, and responsive to market demand, and goes beyond technical issues towards management, marketing, and sustainability improvements.
Continue ensuring farm advisors are well-trained professionals with up-to-date skills.	
Innovation and policy evaluation are becoming more complex and require a wealth of information.	Continue developing information systems, including market intelligence (big data) and research results

Source: OECD (2018b), *Innovation, Agricultural Productivity and Sustainability in Estonia*, https://dx.doi.org/10.1787/9789264288744-en.

Japan (2019)

Box A C.6. Main opportunities and challenges for the food and agriculture system in Japan

- Agriculture in Japan has contracted since 1990, in terms of production value, number of commercial farm households and number of farm workers. The food and agriculture sector is under continuous pressure to raise productivity to keep up with the highly competitive manufacturing sector and increase its exposure to international competition.
- The declining and ageing population in Japan has significant long-term implications for Japan's agriculture, most notably a smaller domestic market and scarce labour force.
- Japan's agriculture has been characterised by small-scale rice production, and structural transformation towards more profitable sectors and more productive large-scale farms has been a major policy agenda in agriculture. However, Japan's agriculture today looks quite different from the traditional image. Agricultural production and land use is concentrated in a small number of large, commercial, often corporate farms. In 2015, the largest 3% of farms produced more than half of the total agricultural production.
- Agriculture has become a more technology- and data-intensive industry, incorporating a diversity of services into value generation.
- Strengthening the sector's capacity to innovate and improving its environmental performance of agriculture is critical to ensure the long-term growth of agriculture in Japan. Innovation in agriculture increasingly depends on technologies developed outside agriculture, such as genetics and digital technologies. The process of innovation in agriculture is becoming highly interactive among a growing and diverse network of stakeholders, institutions and users. More integration of agriculture with other parts of the economy would bring Japan's competitive technology and skills from outside agriculture and enhance innovation and entrepreneurship in agriculture.

Table A C.6. Policies for improving food and agriculture productivity and sustainability in Japan

Key policy recommendations
Develop policy and market environments that are more conducive to innovation and entrepreneurship in agriculture
• Develop a more demand-oriented approach to exploit the diverse demand for Japanese agro-food products in overseas markets, including the international expansion of local production networks.
• Reduce the role of government credit support and increase the role of commercial banks.
• Ensure a level playing field between JA groups, and other agricultural input and service providers by enforcing the Antimonopoly Act and limiting cross-subsidies between financial and agricultural businesses in local JAs.
• Increase the linkage between farm management policy and wider policies focussed on small and medium-sized enterprises (SMEs) to address the entrepreneurial needs of farms beyond agricultural production.
• Develop soft infrastructure to facilitate the digitalisation of agriculture and redesign the hard infrastructure to facilitate the adoption of new digital technology.
• Give farmers more freedom to make production decisions by phasing out commodity-specific support and progressively opening up to international markets.
• Enhance the role of farmers in managing normal business risk by lowering the threshold of revenue loss covered by policy programmes and consider introducing voluntary risk-management programmes.
Fully integrate environmental policy objectives in the agricultural policy framework
• Define agri-environmental policy targets at the national and regional levels based on a systemic assessment of the environmental performance of agriculture with the participation of a wide range of stakeholders.
• Expand the scope of environmental reference levels defined in the current environmental principle to a wider set of environmental issues, including climate change mitigation and biodiversity, and establish environmental targets and reference levels adapted to local ecological conditions.
• Increase cross-compliance conditions on producer support programmes with locally adapted reference levels of environmental quality and design an integrated agri-environmental policy at the sub-national level.

- Better reflect the actual water use in paddy field on water use fees to improve the water use efficiency and include the long-term rehabilitation costs of irrigation system in order to balance the costs and benefits of the investment between current and future water users, and to maintain irrigation infrastructure sustainably.

Establish a more collaborative agricultural innovation system

- Focus public agricultural R&D on pre-competitive research areas with a medium- to long-term perspective and on areas that are not specifically tied to commercial production.
- Introduce co-funding schemes for agricultural R&D with producer organisations to reflect demand in R&D activities; increase overall spending capacity for agricultural R&D investment.
- Increase funding for collaboration, and co-funding with the private sector, foreign researchers and institutions beyond the presently limited number of competitive research grant projects.
- Further integrate agricultural R&D systems with general innovation systems to promote cross-sectoral innovation.
- Clarify the role of national and prefectural agricultural research organisations and consolidate efforts in regional R&D at a broader regional level.

Enhance the capacity of farmers to innovate

- Strengthen the partnership between agricultural education and the agro-food industry, including more participation of professional farms in teaching activities and funding.
- Reorient the curriculum of vocational education in agriculture to develop the skills required of farm managers, provide more structured opportunities for learning, and develop training programmes that combine lectures with work experiences.
- Consolidate prefectural agricultural colleges at a broader regional level to pool resources and develop a unique and specialised agricultural education that is adapted to regional conditions. This should be accomplished in partnership with the private sector.
- Focus on the role of prefectural extension services in areas of public interest, such as promoting sustainable production practices and giving advice on compliance with regulations and government policy programmes; expand the role of private advisory services.

Source: OECD (2019a), *Innovation, Agricultural Productivity and Sustainability in Japan*, https://doi.org/10.1787/92b8dff7-en.

Korea (2018)

Box A C.7. Main opportunities and challenges for the food and agriculture system in Korea

- The agriculture sector is under pressure to meet changing domestic demand, to improve its productivity to keep up with the highly competitive manufacturing sector and to increase its exposure to international competition.
- Per capita arable land area is the smallest among OECD countries. The highly fragmented land ownership structure hinders consolidated use of cropland and limits the scale of operations.
- The livestock sector has expanded rapidly to meet a growing national demand, but the rapid expansion of intensive livestock production has aggravated the environmental pressure from manure emission.
- Income disparity between farm and urban households expanded and income problems concentrate on aged farmers.
- Despite its comparative disadvantage in land-intensive crop production, Korea's potential to export niche agricultural products and processed food that reflect its rich and unique food culture could be explored further.
- Korea's agricultural innovation system can benefit from a strong advantage in Information and Communication Technology (ICT).

Table A C.7. Policies for improving food and agriculture productivity and sustainability in Korea

Main findings	Key recommendations
Incentives for private investment	
Agricultural co-operatives have high market shares in certain input and output markets	Ensure fair competition between agricultural co-operatives and other private agricultural service and input suppliers under the existing provisions of the Monopoly Regulation and Fair Trade Act.
Tax exemption and reduced charges on agricultural inputs may create incentives for excessive use of inputs and natural resources.	Value Added Tax (VAT) exemptions on certain agricultural inputs and the fuel tax exemption should be reviewed to promote more sustainable agriculture.
Capacities and services	
Subdivision of farmland ownership through inheritance is exacerbating land fragmentation.	Reform the property tax system to provide incentives for the succession of farms to a designated successor.
The high price of farmland, reflecting the potential non-agricultural use value of land, is discouraging farm consolidation and encouraging land abandonment.	Apply stricter land conversion regulation to farmland within designated Agricultural Promotion Regions (APR), while concentrating policy support to guide land conversion outside them.
Informal land lease is reducing the incentive to invest in land improvement and rent out land to more efficient users.	Establish a formal registration system of land lease contracts at the local government level.
Free supply of irrigation water reduces the incentive to conserve water use.	Ensure that charges for water supplied to agriculture at least reflect full supply costs.
Professional education for agriculture is attracting less attention.	Reorient the agricultural education system to focus on skills required in the agricultural sector, and not only on formal qualifications.
Agricultural policy	
Overall portfolio of agricultural policy is dominated by policies which are linked to production of staples and to supporting farm income.	Continue rebalancing the portfolio of agricultural support to public investment oriented towards long-term productivity growth and sustainability.
Commodity-specific support constrains farmers' responses to market signals, hinders structural adjustment toward production of more value-added products and increases environmental pressure from agriculture.	Phase out border protection and commodity-specific support to allow markets to play their role in allocating production resources to more high-value-added niche products

Main findings	Key recommendations
A more comprehensive policy approach beyond agricultural policy is needed to address the low-income problem of farm households.	Increase the role of general social security system as an income safety net for farm households by introducing adjusted eligibility criteria and additional incentives for early retirement and resource transfer to young commercial farmers. Take a more bottom-up approach to promoting integrated investments and public services that are geared to local needs to attract non-agriculture industries to locate in rural areas.
Exemption of income tax could impede resource reallocation to more profitable and competitive non-grain agricultural sectors and reduce farmers' incentive to record and manage their farming business activities through bookkeeping.	Take steps to induce farmers to declare income situation to facilitate the self-evaluation of the financial performance of the farm and to allow the government to design better-targeted policies to the household income.
There is no clear definition of reference environmental quality with which farmers need to comply.	Establish a framework of agri-environmental policies which clarifies the reference environmental quality as well as environmental targets.
The growing issue of livestock manure emission requires a more comprehensive policy approach, beyond regulation alone.	Take a multi-dimensional approach to manure management, including regulation, incentives to invest in new technology, capacity-building of producers and building partnerships between stakeholders.
Direct incentives to innovation	
The public sector dominates investment in agricultural R&D.	To let private R&D investment play a greater role, concentrate public R&D investment in areas of public interest, such as environment and resource conservation, and on areas where the private sector would naturally under-invest.
Public R&D projects are implemented largely by a top-down approach and can reflect more the technical demands of commercial farmers.	Allow the participation of a wide range of stakeholders in the public R&D planning and evaluation process to reflect their technical needs. Increase the participation of farmers in R&D projects of public R&D institutions and universities.
A weak network exists between different actors in the agricultural innovation system, including weak public and private partnership in agriculture R&D projects.	Enhance collaboration between different actors in the agricultural innovation system by introducing conditionality of public agriculture R&D projects on collaboration with private sectors, higher education institutions and other public R&D institutions.
Inadequate co-ordination exists between different government agencies engaging in public agricultural R&D.	Strengthen the co-ordinating function of the STCA to form a more consolidated and coherent public agricultural R&D investment strategy.
The public extension system's standardised services are limited to meeting producers' needs, and the development of private technical advisory services is limited.	Redefine the role of the public extension system, leaving more room for private technical service providers in transferring technologies, capital and information. Shift the focus of the public extension service to the provision of public goods such as improvement of environment performance, and to the governance of the whole system to ensure access of small farmers to relevant advice.

Source: OECD (2018c), *Innovation, Agricultural Productivity and Sustainability in Korea*, https://doi.org/10.1787/9789264307773-en.

Latvia (2019)

Box A C.8. Main opportunities and challenges for the food and agriculture system in Latvia

- As a small, dynamic and open economy, Latvia has deployed a broad range of reform initiatives that have driven progress, although generally from low levels, in many of the areas that would nurture future innovation based economic growth. However, progress has been slower in agriculture.
- While Latvia's agriculture faces challenging climatic conditions with a short vegetation period, it enjoys high levels of land and water availability and quality. Its environmental performance is high and, although there may be local environmental stress, no area of national concern has been identified so far despite intensification of mineral fertiliser use over the past decade.
- Today, cereals and dairy farming make up most of Latvia's agricultural output. The structure of commercial farms is dual; livestock farms are typically smaller than the average EU farm, whereas cereal farms are mostly large and export-oriented. At the same time, half of the farms do not market any agricultural goods at all, thus weighing on the sector's performance.
- While Latvia is mostly a service economy, its agriculture holds a relatively large share in the economy. Accession to the European Union and implementation of the Common Agricultural Policy stopped the sector's decline and contributed to its relatively large share in the economy.
- Agricultural incomes have risen, both as a result of direct payments, and indirectly through structural adjustment and support to investments that have contributed to labour productivity growth, to higher yields and ultimately to higher agricultural Total Factor Productivity (TFP). However, the sector has not yet reached its full efficiency and productivity potential.

Table A C.8. Policies for improving food and agriculture productivity and sustainability in Latvia

Main findings	Recommendations
Agriculture	
Non-commercial farms account for about half of farms. They divert productive resources and agricultural support from the sector and may contribute to informality.	Address social issues with social policies. Use advisory services and retraining to support the transition of non-commercial farmers to market oriented activities, within or outside the agricultural sector.
Support accounts for more than 60% of average farm income.	Target support currently based on area or production to the sector's longer-term productivity: education, farm management, investment, co-operation.
Latvia's CAP payments have supported farm incomes and productivity.	Increase incentives to produce higher value products. Address bottlenecks along the value chain.
Farming suffers from value chain inefficiencies and exports raw or low value-added products.	Use CAP RDP funds to strengthen the value chain through producer groups and the processing industry; facilitate co-operation in the creation and diffusion of innovation.
Regulations on land ownership and lease may hinder a more efficient allocation of land resources.	Ease regulations on land ownership and lease to support a well-functioning land market. Consider other instruments to guarantee farmers' access to land and prevent speculation.
Access to credit has improved, from low levels. National policies support farm access to credit.	Evaluate the recent restructuring of Altum and the adequacy of the institutional framework for the sector's credit needs.
Latvia's CAP RDP choices support investments to improve the overall performance and competitiveness of agricultural holdings. Production-distorting support remain in specific commodity sectors. Voluntary coupled support absorbs half as much budget as the annual expenditure under the CAP RDP competitiveness priority.	Align policy signals, reduce commodity-specific support and use budgets to encourage the longer-term productivity and competitiveness of the sector.

Main findings	Recommendations
More than two-thirds of farm labour is unpaid.	Accompany the transition of unpaid family labour into the formal labour force. Provide a legal status to unpaid agricultural labour and adjust tax, social security and pension systems accordingly. Improve job opportunities in and outside the sector for unpaid farm labour through education and better connection to job markets.
Unemployment is higher in rural areas. Labour costs have increased while they remain below EU28 levels.	While taking into account job quality aspects, increase recourse to contracting for farm labour and farm services and consider relaxing wage obligations for non-EU labour to encourage employment, increase farm productivity and the viability of rural areas.
Subsidies per head of livestock tend to intensify livestock production and increase the environmental load. Diesel fuel and natural gas used in agriculture benefit from reduced excise tax rates and add to the sector's environmental load.	Eliminate support based on animal numbers and production volumes that adversely affect the environment. Payments per ha of grass rather than per animal head could be a first step towards less environmentally harmful practices. Gradually reduce the excise tax rebates for diesel fuel and natural gas used in agriculture and encourage the use of renewable energy.
Innovation dissemination and take-up	
Little is known on the factors that drive the adoption of innovation at farm level.	Use CAP RDP funds to support farmer access to advisory services farmer participation in innovation networks Identify and monitor factors that drive the adoption of innovative technologies, practices, at the farm level and along the food chain.
Advisory and education services in agriculture and food production have become more widely available. At the same time, there is a skills shortage in the farm workforce.	Bridge the skill gap and improve the educational attainment of farm holders and train qualified specialists. Further strengthen knowledge transfer activities to facilitate better access of the farming workforce. Harness the farm advisory system to facilitate the participation of farmers in training and expand innovation take up. The system can also be used to support small farms' assessment of their profitability and transition to more profitable activities in and outside the sector.
Latvia has directed very little CAP RDP funds to risk management instruments. While innovation can improve farm resilience; associated investments may increase farmers' financial vulnerability.	Promote risk management and strengthen risk management tools.
Education	
Adult participation in training has increased significantly, although from low levels and mostly in non-formal education.	Strengthen the availability, accessibility and affordability of lifelong development opportunities both in qualifying and informal agricultural education.
The education system needs to adapt to the changing demography. The Employment Council, established in 2016, addresses labour market issues, including those related to education and the impact of demographic trends.	Attract foreign students and encourage lifelong learning to enlarge the pool of students.
The share of Latvia's tertiary educated students in the science, technology, engineering and mathematics (STEM) fields is below the OECD and the EU average rates. More students have chosen STEM fields since 2015.	Encourage student participation in STEM fields to offer a supportive environment for the creation, adoption and acceptance of innovative technologies
Research and innovation	
The ZTAI sets general innovation policy objectives for innovation in the bioeconomy in general. Numerous policy instruments in place and available public funds are significant for agricultural innovation.	Define a specific agricultural innovation strategy using a bottom-up approach to identify the sector's specific needs and gaps in the agricultural innovation system. Improve the co-ordination among the policy instruments and public funds. Monitoring their implementation, evaluate their direct outcomes and socio-economic and environmental impacts.
There is insufficient participation of research institutions in EU and other international initiatives.	Ensure stable funding for the research infrastructure in food and agriculture to strengthen capacity to participate in collaborative efforts. Maintain public funding to enable co-operation with private companies and with foreign research organisations
Latvia's research and innovation capacity lacks a critical mass to contribute to the needs of the agricultural sector.	Foster regional collaboration in research and innovation to overcome the market-size limitations.
Little private expenditure is invested in agro-food R&D	Use public procurement to stimulate innovation. Strengthen public-private co-operation, in particular on projects directed towards the market introduction of research results.

Main findings	Recommendations
Better information and better data are needed to support better decision making from field to policy making.	For farm managers: use farm level data and improve access to information on markets, regulations and policy instruments to enhance farm and risk management choices. For policy makers: better data allows better targeting of policy instruments to objectives and needs, a more accurate monitoring of outcomes and, altogether, improve policy relevance. Improve capacity by participating in internationally comparable data collection and reporting exercises.

Source: OECD (2019b), *Innovation, Agricultural Productivity and Sustainability in Latvia*, https://doi.org/10.1787/9789264312524-en.

Netherlands (2015)

Box A C.9. Main opportunities and challenges for the food and agriculture system in the Netherlands

- The Netherlands is a small, densely populated and urbanised European country.
- The Dutch food, agriculture and horticulture sector is innovative and export oriented, with high value-added along the food chain and significant world export shares for many products.
- Continuous adoption of innovation has permitted to reach high levels of productivity, and sustained productivity growth, in particular at the farm-level, in a context of increasing environmental regulatory constraints.
- Characterised by high land intensity, Dutch agriculture generates significant pressures on the environment.
- The challenge is whether marginal improvements in current technologies and know-how will be enough to pursue current rates of productivity growth, sustainably, and face future challenges, including those linked to climate change.

Table A C.9. Policies for improving food and agriculture productivity and sustainability in the Netherlands

Main findings	Key recommendations
Incentives for private investment	
Reforms have significantly reduced regulatory barriers to entrepreneurship, but there is still scope for reducing complexity and transaction cost related to compliance with regulations.	Efforts to minimise administrative costs of compliance and reduce the costs of registering products, and reduce length and simplify procedures, need to continue. Regulators need to keep up pace with innovation.
Access to finance for innovative firms has decreased since the financial crisis has weakened Dutch banks. Credit support is generally targeted to investments to improve competitiveness and sustainability, in particular compliance with environmental, food safety and animal welfare regulations.	Focus public support to investment in areas where financial markets fail to provide funds. Simplify the architecture of credit support programmes to improve access and targeting. Identify market failures in credit and land markets to design better targeted agricultural policies.
Tax incentives for innovation have increased in recent years and account for over three-quarters of government support to business innovation.	Rebalance the policy mix by complementing the current focus on R&D tax credits with competitive, well-designed direct support instruments, e.g. for joint R&D projects with knowledge institutes, and instruments used in the top sectors approach.
Capacities and services	
Economic activities and rural populations benefit from an excellent infrastructure network and good access to public services.	--
Demand for labour and skills in agri-food and nature management is strong.	Increase the flexibility of employment and migration policy to facilitate labour force moving into these areas with strong demand.
This demand is being addressed in collaboration with the education system, but delays in the response may lead to temporary shortages of skills.	Ensure public funding for education and knowledge institutions enables them to continue to offer relevant education and training. Ensure students are able to move to areas with attractive employment prospects such as agri-food education, by ensuring equal funding. Facilitate discussion between education and knowledge institutions and the industry to identify current and future skills. Facilitate further life-long learning and upgrading of skills in the labour force. Continue to develop business management programmes, including for future researchers and farmers, to facilitate the valorisation and adoption of knowledge.
Agricultural policy	.
Dutch implementation of the CAP generally aims to facilitate productive investment.	Develop a long-term vision reconciling productivity growth and sustainability and reduce policy uncertainty. Continue to limit the provision of coupled payments to very targeted and temporary measures.
Broad-based support measures affect the environmental performance of agriculture	Strengthen the ability of agricultural policy to improve the environmental performance of agriculture, by focusing agri-environmental measures to objectives and outcomes rather than on process and EU regulation constraints; revisit the balance between regulation and economic incentives in view of fostering environmentally-friendly innovation.

Main findings	Key recommendations
Farmers' linkages with the agricultural innovation system could be further encouraged.	Make use of the opportunity given by the CAP to recognise Producer and Branch Organisations and support the participation of farmers or farmers' organisations in knowledge networks.
The government has developed a good information base in collaboration with the sector	Maintain the good information base and analytical capacity to monitor progress, evaluate policies and guide farmers' decisions, with specific attention to innovation adoption and environmental practices.
Direct incentives to innovation	
Institutional developments have made the system more collaborative and demand-driven and have strengthened the role of the private sector in guiding investment.	Strengthen the role of the government in defining long-term objectives for R&D and innovation, taking into account long-term challenges and societal demand. Facilitate the organisation of producers and the industry to enable them to contribute more effectively and efficiently to the agricultural innovation system, including through participation in networks or formulation of demand.
The innovation policy targets specific sectors, resulting in weak links across sectors and policies	Improve policy co-ordination amongst agricultural, industrial, innovation, education, and regional policies, and policy stability.
Sources of R&D funding have become more uncertain.	Facilitate access to other sources of funding: How could revenues from IPRs be increased? Explore ways to increase Intellectual Property revenues or generate additional funding from royalties or levies.
There are concerns that the government is paying a larger share of the investment than is apparent, including through tax incentives that provide the majority of support to innovation in the private sector	Ensure the contribution that business makes to public-private partnerships is commensurate with the benefits they get.
That the system limits research in some areas	Identify and fund areas not covered by public-private partnerships, with specific attention to food safety, sanitary and phytosanitary issues, economic analysis, societal issues of no direct interest to the private sector, longer term and more risky issues. Explore ways to generate new (breaking through) ideas to overcome current constraints, for example through demand-driven mechanisms, including to develop technologies and systems allowing for a better management of natural resources and improved resilience to risks. Ensure public co-financing is available for participation in EU programmes and international collaborative efforts.
Evaluation of the innovation policy could be strengthened	Continue developing information systems, including market intelligence (big data) and research results, as innovation and policy evaluation become more complex and require a wealth of information. In particular, continue to monitor innovation adoption and environmental performance in surveys to better understand determinants and policy impact. Continue to use and share innovative methods to reduce collection costs and improve farm and firm participation. Develop indicators and tools to evaluate the performance of the agricultural innovation systems in general, and innovation policy regularly, taking longer term effects into account.

Source: OECD (2015d), *Innovation, Agricultural Productivity and Sustainability in the Netherlands*, https://dx.doi.org/10.1787/9789264238473-en.

Sweden (2018)

Box A C.10. Main opportunities and challenges for the food and agriculture system in Sweden

- The main socio-economic challenge facing the Swedish food and agriculture sector is achieving sustainable growth and employment, and maintaining high environmental and animal welfare standards, given the relatively weak competitiveness in several parts of the sector.
- The food and agriculture sector is a small and decreasing part of the Swedish economy in terms of output and employment. Structural changes in agriculture over time have resulted in a sharp decline in the number of farmers, and farms have become larger and more specialised.
- While Sweden does not have a comparative advantage overall in food and agriculture production, there is a high degree of heterogeneity and some sectors, such as vegetables and the downstream food supply chain are competitive.
- Since Sweden joined the European Union, total factor productivity (TFP) for the agricultural sector as a whole has grown at a slightly higher rate than the EU28 average over 1995-2016. The growth in agricultural TFP is mainly due to structural changes such as the concentration of production in fewer, larger and more efficient farms.
- High awareness of animal welfare, food safety and environmental issues by consumers and the citizens.
- Sweden has a robust innovation-oriented economy and the agricultural innovation system is mostly integrated in the general innovation framework.
- Making growth more sustainable, inclusive and green is a key overall policy objective.

Table A C.10. Policies for improving food and agriculture productivity and sustainability in Sweden

Main findings	Key recommendations
Incentives for private investment	
Regulations in Sweden are more extensive and complex than those in other EU member states	Efforts to simplify domestic regulations related to the environment, animal and crop health, and animal welfare that go beyond EU regulations by reducing administrative and compliance costs should be continued to be a priority. In particular, there is a need for better policy integration and collaboration between businesses in the food and agriculture sector, policy makers and regulators, so as to ensure that encourage the development and adoption of innovations and improve productivity and competitiveness of the food and agriculture sector.
Sweden does not have an overall comparative advantage in agri-food production	Strengthen efforts to focus agri-food research and innovation on knowledge-intensive high-tech areas including biotechnology, green energy, and food waste, and shorten and improve food and agriculture supply chains. Sweden has a highly developed knowledge economy, is well placed in this regard.
Insufficient technology transfer in remote areas	Improve technology transfer across in the food and agriculture system, in particular with the aim of enhancing access in remote regions.
Concerns about the high market concentration in Swedish retail food industry	Assess competition and functioning of the food production and food retail markets through, for example, the Swedish Competition Authority.
Strict animal welfare regulations	Consider establishing a scientific council on animal welfare as suggested in the 2017 Food Strategy.
Capacities and services	
Meeting labour market needs in the food and agriculture sector	Implement and facilitate pro-active skills policies – through for example the creation of education councils for the sector to promote life-long learning, and labour mobility to alleviate shortages of high-skilled workers in the agro-food chain and to better identify current and future skill requirements of the sector. Assess the support needs of new entrants to farming and identify their potential business and organisational models, such as which knowledge they manage and how they acquire it, the use of technology, their access to capital (including land) and financial management, their marketing strategies, and co-operation initiatives.

Main findings	Key recommendations
Ageing agricultural workforce	Prioritise inter-generational renewal in agriculture by developing tailor-made schemes that target Swedish young farmers. Assess the extent to which land regulations, taxation, inheritance law, territorial planning and agricultural policies such as direct payments impede generational renewal.
Rural areas face a declining population and shortage of skills.	Fully connect farmers and rural population to the digital economy by ensuring reliable high-speed internet access across all rural areas and upgrading the people's skills and business practices so that they can fully benefit from these new technologies. Strengthen the socio-economic foundation of the rural economy by stimulating the bio- and circular-economy in sustainable agricultural, forestry and agri-forestry business models. Establish a mechanism to engage with stakeholders with the aim of improving the coherence of rural development policy.
Declining number of students enrolled in agri-food courses	Strengthen the co-ordination between agricultural education institutions and the food and agriculture industry, and facilitate discussions between education and knowledge institutions and the industry so as to identify the skills needed for future development.
Agricultural policy	
Reform of agricultural policies	Prioritise further reform of agricultural policies by advocating the implementation of results-based, nationally specified agricultural policies (devolution) that reflect the diversity and uniqueness of Sweden's agri-environment, within the broad guidelines agreed at the EU level. Identify appropriate policy measures that target the development of agricultural activities that are potentially financially viable, as well as those that ensure the provision of sufficient collective or public goods (environmental, cultural, social values) provided by agricultural activities.
High reliance of agricultural incomes on support	Reduce the relative importance of government support in agricultural incomes and increase farmers' returns from the market through investment and strengthening the knowledge-based for farming through more research and innovation by encouraging further integration of agriculture in the Swedish Innovation System.
Investment support	Assess investment needs and enhance the effectiveness of public investment support by focusing on areas where financial markets fail to provide funds for the provision of public goods, and better integrate business advice and synergies with research and innovation. Boost investments into innovation, modernisation, farm restructuring, diversification and uptake of new technologies and digital-based opportunities such as the use of big data, precision farming and clean energy. New business models as well clarity around the rules on data sharing will be necessary before the full potential of these technologies can be exploited.
Further enhancing environmental sustainability	Ensure that environmental and climate change concerns continue to be taken into account when developing and assessing policies that can contribute to productivity and competitiveness. Encourage performance-based evaluation of policies and implement measurable indicators of performance. Apply the polluter-pays-principle more systematically to hold farmers accountable for all harmful environmental effects from crop and livestock pollution; for example, by adding taxes on fertilisers and issuing penalties where these contribute to water pollution. Strengthen efforts to provide targeted and tailored advice to farmers on sustainable technologies and practices.
Direct incentives to innovation	
Linkages between basic research, applied research and the industry could be improved	Strengthen linkages between basic research, applied research and the industry by undertaking the following actions: Develop a long-term strategy for research and innovation in the food and agriculture chain by: clarifying the institutional roles of SBA, SLU and RISE, establishing a platform to co-ordinate their tasks, or by merging them within RISE (the Research Institutes of Sweden Holding AB); creating a national council to monitor R&D policies of institutions; setting up a national agricultural research institute to carry out applied R&D; and assessing the effectiveness of current funding allocations to research councils and universities. Encourage active participation by stakeholders, producers and the industry in RISE, EU EIP-Agri and international networks to transfer innovation in agricultural practices, which focus on agri-food research and innovation on knowledge-intensive high-tech areas. Ensure that farm advisors are well-trained, and are in possession of the most up-to-date practical knowledge and skills. Strengthen research evaluation by improving the internal system for quality assurance. Develop indicators and tools to evaluate performance and monitor the rate and quality of innovation in the food and agriculture sectors. In addition to traditional indicators on efforts (e.g. R&D expenditures) and outcomes (e.g. number and quality of patents), such indicators should include impact (e.g. the rate of innovation adoption, TFP and environmentally adjusted TFP growth, and agri-environmental indicators).

Source: OECD (2018d), *Innovation,* Agricultural *Productivity and Sustainability in Sweden*, https://dx.doi.org/9789264085268-en.

Turkey (2016)

Box A C.11. Main opportunities and challenges for the food and agriculture system in Turkey

- Turkey is a relatively well-endowed in land and water, and benefits from favourable climatic conditions for agriculture.
- Agriculture still employs almost a quarter of the active population.
- The Turkish agro-food sector has the potential to significantly contribute to the country's overall economic development, but its ability to do so will depend largely on productivity growth.
- Rigidities in the labour market, regulations, taxation and education, and lacking infrastructure investment, particularly in rural areas, slow the sectors' overall productivity growth.
- Irrigation expansion can help the growth of the sector if accompanied by improved and reinforced water management and policies.
- An essential challenge will be for Turkey to develop its rural economy to enable people to generate income outside low technology agriculture.

Table A C.11. Policies for improving food and agriculture productivity and sustainability in Turkey

Main findings	Key recommendations
Incentives for private investment	
Businesses face fairly rigid regulations, and there is room to improve conditions for doing business	Reduce the overall regulatory burden on entrepreneurship, particularly by simplifying regulatory procedures and administrative burdens on start-ups. Ensure coherence across regulatory areas and different administrative levels. Undertake a comprehensive review of business regulations and procedures to determine critical areas for further reform.
There has been progress in the development of environmental regulations, but implementation, monitoring, and assessment are also important	Continue the development and consolidation of environmental laws and regulations, and strengthen their implementation; ensure that appropriate human and institutional resources are deployed to fulfil environmental targets; improve the cost-efficiency of regulations and reinforce their acceptability.
The tariff regime is liberal overall, but better trade facilitation could increase gains from trade	Improve trade facilitation by expanding the application of internationally-harmonised standards, certification procedures and mutual recognition agreements. Simplify border formalities, ensure the disciplining of fees and charges, and support transparency and availability of information
The tax burden on businesses is moderate and substantial tax concessions are provided, but there are de facto distortions in business taxation	Continue efforts across policy areas to eliminate business informality, in particular, in order to reduce de facto distortions in the tax treatment of different-sized businesses.
Capacities and services	
The infrastructure gap is being reduced and future plans are ambitious	Pursue improvements in infrastructure, with a focus on impact assessment and the monitoring of infrastructure projects in terms of environmental sustainability, climate resilience, and changes in the availability and quality of agricultural land.
Stronger governance, monitoring and impact analysis is needed	Simplify governance and facilitate the co-ordination of infrastructure development initiatives at different administrative levels and with different scopes.
The rigid labour system impedes more modern and efficient businesses from developing, social safety nets remain insufficient.	Progress with the planned labour reforms; allow the formal sector greater flexibility in labour arrangements; strengthen unemployment safety nets, job placement, and up-skilling programmes.
Despite recent progress, education and skills require a major boost	Ensure that efforts to meet higher targets for participation in education take place in parallel with improvements in the quality of education.
Rural populations in particular need to become better educated	Enhance measures and the underlying resources for greater inclusion of rural populations in the education system, rural women in particular; align efforts to improve participation rates with social policies, exploit low cost distance-learning methods.

Main findings	Key recommendations
Various initiatives for better education have been undertaken and further objectives defined	Pursue the promotion of the non-government provision of education, with a special focus on vocational education and training; promote public-private partnerships in the area of education; co-operate with industry and professional organisations in the creation and updating of training packages, job placements, and advocate agro-food careers among those in vocational and higher education.
Agricultural policy	
Boosting domestic and export supplies is the principal orientation of agricultural policy	Move towards the more balanced distribution of public resources, including by down-sizing and targeting the eventual elimination of transfers to state economic enterprises and agricultural co-operatives.
Environmental sustainability has become an explicit policy objective and specific policy measures are emerging	Improve the efficiency of water use in a combined effort to develop and modernise irrigation systems, to put in place formal, transparent and simple water-sharing mechanisms, and to ensure the financial viability of irrigation systems. Integrate climate change adaptation and mitigation as a cross-cutting aspect of agricultural and agri-environmental policies
The current producer support structure is unlikely to be effective in stimulating long-term productivity gains	Move away from support which alters output and input prices and from product-specific subsidies. Increase focus on investments in people, strategic physical infrastructure, and agricultural innovation system that are responsive to the needs of producers and consumers. Consider an assessment of existing subsidised agricultural insurance, with regard to its longer-term financial and actuarial soundness and in view of climate change risk.
Important productivity-enhancing general services have a small spending share and require a better balance	Exploit the possibilities presented in the new national agricultural information system to generate more comprehensive and up-to-date evidence on agricultural productivity trends and its determinants.
Rural diversification and environmental objectives attract little resources	Consolidate and enhance rural diversification activities across various agencies and within various programmes; consider a co-ordinated national rural diversification framework that focuses on the development of rural industries; increase the emphasis on rural diversification in regional and rural development investments.
Direct incentives to innovation	
R&D intensity in the agro-food sector lags behind other economic sectors and is low internationally	Enable increased R&D investment and R&D conduct by agricultural and food businesses; investigate the impediments to participation by these businesses in R&D compared to other economic sectors; consider actions to raise awareness amongst agricultural and food businesses of the opportunities for business development through R&D and innovation.
Agribusiness participation in R&D is increasing, aided by policy stimuli, but is still limited	Undertake an impact evaluation of tax incentives for business R&D in terms of their thematic focus, their association with national general and sectoral R&D priorities, and the alignment of incentives across R&D providers of different sizes.
IPR regulation has been considerably strengthened, while procedures and law enforcement require improvement	Raise IPR awareness amongst potential innovators, simplify procedures and regulations that protect IPRs, and strengthen law enforcement; exploit the flexibilities in country's international IP bindings to increase the availability of IP-protected products in the agricultural and food sector..
Efforts are made to strengthen knowledge flows to farmers and industry	Strengthen feedback flows from local to higher levels of the public extension system in; consider increasing resources and staff to re-inforce the extension system at local level; continue encouraging the provision of extension services by private consultants
There have been rapid increases in R&D output, however further progress needs to be made with regard to its quality and impacts	Exploit further opportunities for bilateral and multilateral co-operation in R&D and technology transfer.

Source: OECD (2016a), *Innovation, Agricultural Productivity and Sustainability in Turkey*, https://dx.doi.org/10.1787/9789264261198-en.

United States (2016)

Box A C.12. Main opportunities and challenges for the food and agriculture system in the United States

- 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.
- High Total Factor Productivity (TFP), largely driven by farm consolidation and the continuous and widespread adoption of innovation, enables sustained agricultural production growth.
- TFP growth has been achieved with reduction in environmental pressures, but there still exist areas with significant environmental problems linked to agriculture.
- US food and agriculture can take advantage of growing and diversifying demand, at both the national and global levels. Yet market, climate and resource-related constraints create new challenges to meet these demands, while maintaining past levels of high productivity and improving sustainability.

Table A C.12. Policies for improving food and agriculture productivity and sustainability in the United States

Main findings	Key recommendations
Incentives for private investment	
Competition policy facilitates adjustment and does not slow market-driven consolidation, but the issue of concentration in food and agriculture attracts widespread attention	Establish a system to monitor with greater regularity the impact of high concentration of firms in the agri-food sector.
Increasing vertical co-ordination (including via contracting) in the agri-food chain could potentially lead to a lack of transparency and the exercise of market power.	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.
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.	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.
Regulatory frameworks and guidance are being reviewed with a view to facilitating new developments, while maintaining trust in the system.	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, 2015e) 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 report also recommends increasing reliance on environmental taxation. There is scope for applying this recommendation to agricultural activities.
Capacities and services	
Telephone and internet coverage and use are unequal across regions and by technology.	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.
The labour market functions flexibly, but the sector faces labour shortages, in particular for hired, seasonal labour.	Implement pro-active skills policy and information systems to facilitate the labour force moving into areas with strong demand.

Main findings	Key recommendations
The United States is a global leader in tertiary education, but performs poorly below secondary level, despite the high level of investment.	Assess the relevance and cost-efficiency of secondary education in agriculture-related areas in providing the skills required for a modern economy. Improve co-ordination 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.
The agricultural education system faces a number of challenges, arising in particular from the broader range of knowledge required in this sector.	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 co-ordination 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	.
Producer decisions respond largely to market signals, although resource allocation across commodity sectors could be improved.	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
The emphasis on insurance and risk management policy tools increases.	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.
Insurance programmes remain commodity-specific.	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.·
The design of agri-environmental programmes has improved, with better targeting of a broader set of environmental issues, but environmental issues remain at the local level.	Strengthen the role of the federal government to co-ordinate 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
The good information base and analytical capacity supports the design and evaluation of policies.	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.
Direct incentives to innovation	
The agricultural innovation system needs to continuously adapt to new innovation challenges.	Establish a national innovation office to increase coherence and continuity in implementation of the national innovation strategy. 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.

Main findings	Key recommendations
Public funding of agricultural R&D has decreased over time, building complementarity with private R&D. Reduction in public funding increases pressure for higher focus and efficiency, but basic public capacity is needed for the functioning of the whole system	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.
Agricultural research funding has evolved to better exploit public-private complementarity.	Explore further research collaboration opportunities at multilateral level or with non-traditional partners, in particular to deal with global issues.
Federal funding of public extension services has also decreased and the consolidation of county programmes has resulted in a reduction of the number of county agents	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.
Efforts to improve transparency and evaluation will contribute to greater relevance and trust.	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. 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.

Source: OECD (2016b), *Innovation, Agricultural Productivity and Sustainability in the United States*, https://dx.doi.org/10.1787/9789264264120-en.

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ISBN 978-92-64-87589-0 – 2019

OECD Food and Agricultural Reviews

Innovation, Productivity and Sustainability in Food and Agriculture

MAIN FINDINGS FROM COUNTRY REVIEWS AND POLICY LESSONS

Markets that function well within a stable regulatory and policy environment are key to improving the productivity and sustainability of the food and agriculture sector. This report contains the main findings and policy lessons gained from a series of wide-ranging country reviews on how government policies can improve sectoral productivity and sustainability through their impact on innovation, structural change, natural resource use, and climate change. Improving the policy environment would require rolling back those policies that distort markets the most and retain farmers in uncompetitive and low-income activities, harm the environment, stifle innovation, slow structural and generational change, and weaken resilience.

Agriculture policy should focus instead on measures that facilitate the uptake of technologies and practices that use resources more efficiently and sustainably, and which contribute to reducing greenhouse gas emissions. Of equal importance are: a more collaborative approach, more effective governance systems, the development of long-term strategies, strengthened linkages between national and international actors, and comprehensive and coherent evaluation procedures. Public funding of food and agricultural research is also crucial, and private efforts need to be strengthened, including through public-private partnerships. Finally, improving overall policy coherence would contribute to building trust, and to increasing policy effectiveness at each step of the food and agriculture chain.

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