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# DYNAMICS OF FARM PERFORMANCE AND POLICY IMPACTS: MAIN FINDINGS

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# Dynamics of Farm Performance and Policy Impacts: Main Findings

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Increasing productivity at farm level is a key policy objective across most countries and fundamental to the overall performance of agricultural and food systems. This paper applies dynamic statistical methods to farm level data in order to identify the determinants of farm performance over time, in terms of productivity and measures of local sustainability. The analysis sheds light on the effects of policies on productivity, and the links between productivity and sustainability outcomes. It draws on key findings from seven case studies: crop farms in Australia, France, Italy and the United Kingdom (England and Wales); and dairy farms in the Czech Republic, Denmark and Norway, with different sample periods, from the most recent three decades to the last five years. A key finding is that policy changes increasing the degree of decoupling of payments have a positive impact on productivity. Furthermore, with the right incentives, productivity growth can be more locally sustainable insofar as farms can produce more output with less inputs that harm the environment. The detailed background work on the seven samples of crops and dairy farms in the above countries is available in *OECD Food, Agriculture and Fisheries Paper* N°165.

**Key words**: Agriculture, productivity, technical change, environmental sustainability, drivers of performance, farm structure, innovation, agricultural policy, decoupling

**JEL codes**: D24, O31, O33, Q12, Q18

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# Executive summary

Increasing productivity performance at farm level is a key policy objective across most countries and fundamental to the overall performance of agricultural and food systems. The assessment of such performance and its evolution over time is a key piece of information for both the assessment of policy impacts and the design of productivity-enhancing policies. The results in this paper show how in-depth analysis of farm level data using innovative statistical methods can provide empirical evidence that can inform policy assessment and design. This study provides evidence from a large number of case studies covering different countries and agricultural systems.

The analysis presented in this paper complements previous static productivity analyses by offering insights into the dynamics of farm classes with different productivity characteristics, as well as into the impact of policies. Seven samples of farms are studied: crop farms in Australia, France, Italy and the United Kingdom (England and Wales), and dairy farms in the Czech Republic, Denmark and Norway, with different sample periods, from the most recent three decades to the last five years.

## Diverse dynamics of farm performance

An increase in productivity over time is common to all countries and most crop farm classes. However, productivity dynamics differ widely across countries in the crop farm case studies. There is a notable difference between Australia and Europe in terms of the evolution of different productivity farm classes. The productivity gap between the most and least performant classes increased in Australia. This divergence is due to particularly strong productivity growth among the most productive farms. Australia's dynamics of crop farm classes tend to favour the most productive farm class, which became larger, but with a small class of low productivity farms that has not caught up, particularly in recent years.

On the other hand, productivity in French, Italian and UK crop farms has converged across farm classes, without significant productivity improvements amongst the most productive classes. In France and Italy convergence in productivity across farm classes occurs by reductions in the productivity of the most productive class. In the United Kingdom convergence in productivity across classes is driven by a large increase in the numbers of farms in the most productive class that were originally less productive farms during the sample period.

The different patterns do not always correspond to distinct policy environments that distinguish the Common Agricultural Policy in France, Italy and the United Kingdom from the low support deregulated policy environment in Australia. The increase in the relative size of the most productive class was largest in the United Kingdom followed by Australia and France, with very slow dynamics in Italy. The recent process of dynamic adjustment across farm classes stalled by the end of the period in both Australia and France, but in the United Kingdom it is estimated to be on a pathway of continued improvement.

The productivity dynamics of dairy farms also differ across countries in the three case studies. However the differences do not seem to have clear correlations with current policy environment. Productivity increased in all three country studies, but, while in Denmark the relative size of the most productive class largely increased, in Norway and the Czech Republic the most productive farm classes reduced their shares. The spread of productivity across different farm classes diverged over the sample period in the three country studies, implying increasing differences between the most and least productive farm classes.

## The policy environment matters

The policy analysis in this report employs a methodology that is useful for analysis of the EU 2003 decoupling reforms and their relative impact on crop farms' productivity. The different modalities of implementation of decoupling reforms in France and England have a statistically significant impact on the level of productivity of their farms. France applied minimum decoupling (about 75% of payments decoupled) paid at the existing historical rates, while England applied full decoupling and adjusted farm level payment rates.[1] English farms were able to increase their productivity and overtake the comparable sample of French farms during the period after the reform 2003-08.

According to the Difference in Difference analysis in this study, the full decoupling approach in England created incentives for crop farms to further optimise their scale, to decrease their average cost and increase profitability. The likely microeconomic mechanism behind this result is that: decoupling implies more freedom to adjust and allocate inputs and outputs in the farm. Taking advantage of this opportunity, English crop farms moved closer towards the optimal crop production frontier with a significant gain in technical efficiency. The analysis of the dynamics of switches to more productive classes reveals that English crop farms generated permanent productivity improvements, in contrast with the slowing of the dynamic adjustment among French crop farms. This recent dynamics implies an evolution towards the most productive class that could be sustained in the long term.

## Higher productivity is key to improving sustainability

The environmental performance indicators used in this work capture only limited dimensions of sustainability due to data constraints (only the use of chemicals is common across all case studies) and, consequently, results on environmental performance have to be interpreted with caution. Moreover, there may be trade-offs between local and global sustainability in the case where lower productivity farms have a lower environmental footprint, but lower productivity leads to a global increase in agricultural area and associated land use change. In general, this study does not find a clear pattern in the relationship between productivity and local environmental sustainability. This lack of pattern reflects the fact that increases in productivity can follow different sustainability performance paths. With the right incentives, higher productivity helps farms to produce more output with less variable inputs that harm the environment.

Only the Czech Republic dairy farm case study shows the most productive class also performing highest in terms of local sustainability performance. In Danish dairy and UK crop farms the opposite tends to be true: the less productive farms are the most environmentally sustainable. But the pattern productivity-sustainability is not clear for Italian and French crop farms. Within-country comparisons over time do not provide a clear relationship between productivity and sustainability either. For instance, in Norway the environmental performance of the most productive dairy farm class has deteriorated over time, while its productivity has significantly increased; at the same time, moderate increases in productivity of least productive farms have been associated with increases in sustainability. In Australia increases in productivity and sustainability indexes over time occurs for both most and least productive farm classes.

[1] This implementation model was called hybrid regional farm level and implied a middle way between flat regional rates per hectare and historical rates.

## Drivers of productivity improvements at farm level

The analysis of the dynamics of productivity performance in the seven case studies presented in this paper provides an estimation of the main drivers of productivity improvement, in particular those farms that have permanently switched performance class. The drivers that are statistically significant vary across different countries and do not follow a clear cross-country pattern. The following drivers are found to be significant for at least one of the case studies. With respect to farm structure related characteristics, those farms exhibiting permanent productivity improvements tend to have less family labour, a lower land endowment and, in the case of dairy farms, a smaller herd size.

In some cases studies, higher use of inputs that can be environmentally harmful (such as fertilisers) shows a negative correlation with the probability of a farm showing a permanent productivity improvement. However, organic farming is found to be negatively correlated with productivity improvements in Denmark, indicating a potential trade-off with respect to organic production. Most innovation related characteristics have a positive correlation with the probability of being a productivity improver. This includes contract farming, share of rented land and net investment. The technology related variables such as capital intensity show different correlations signs across case studies. Among the household characteristics, female farmers are found to be more likely to be productivity improvers for UK crop farms and Norwegian dairy farms, while gender is not significant in the other cases studies.

# 1. Objective and approach

Significant efforts have been made to identify the drivers of farm performance in terms of productivity and sustainability.[2] A report containing an empirical analysis of farm performance across eight countries and seven different farm types has been made available in the public domain (Sauer and Moreddu, 2020[1]; OECD, 2020[2]; OECD, 2020[3]). That analysis considered fundamental differences across farms with respect to production structure, sustainability of production, innovation of operations, individual characteristics as well as farm location. Farms were grouped in technology classes, which were defined statistically using a latent-class estimation procedure linked to a principal component analysis. A number of multi-dimensional indicators define the farms' characteristics, on the basis of which the estimation procedure groups them into two or three distinct classes. The empirical analysis provided evidence on the productivity performance and the rate of technical change in the different technology classes. The empirical analysis also considered correlations between the different performance indicators.

This new report adds value in two different directions. First by providing evidence on the dynamic evolution of this performance and the main factors that determine different performance paths. Second, by analysing the impact of a selected set of policy examples to investigate the effects of these policies on productivity and sustainability performance. The contribution of this work to the literature is providing novel empirical insights and demonstrating innovative methods.

This work builds on the estimated farm technology classes for various production types and countries in (OECD, 2020[2]),[3] including the identification, description and evaluation of essential characteristics of farms and their respective technologies in each class. This study includes the following analysis of the dynamics of farm performance: (i) the systematic analysis of farms' class membership over time; (ii) the switching patterns among farm classes; and (iii) the characteristic of farms that improve their productivity performance and switch to a more productive class. The analyses are applied on representative country cases covering relevant production types (dairy and arable). The choice of countries and sectors was made based on policy relevance as well as statistical representativeness. Seven case studies have been included: crop farms in Australia, France, Italy and the United Kingdom, dairy in the Czech Republic, Denmark and Norway.

This study also includes the evaluation of significant drivers for class membership patterns in response to specific policy measures using innovative statistical methods, and providing evidence for the impact of selected policy schemes on productivity, sustainability and performance dynamics. Two case studies on policy impacts are reported: (1) the CAP Pillar I 2003 decoupling implementation in two countries with very different policy choices (France and the United Kingdom), and (2) dairy farming subsidies in the Czech

[2] This work has raised significant interest as illustrated by countries' participation in the project and the positive feed-back on results, which have been regularly discussed at meetings of the Farm Level Analysis network and the APM Working Party. The result consist of three publically available documents ([TAD/CA/APM/WP(2020)2/PART1/FINAL], [TAD/CA/APM/WP(2020)2/PART2/FINAL] and [TAD/CA/APM/WP(2020)2/ANN/FINAL]) which are cited as (OECD, 2020[2]) for the first and (OECD, 2020[3]) for the latter two, and the OECD Food, Agriculture and Fisheries Paper (Sauer and Moreddu, 2020[1]) .

[3] See methodology in Annex A of the final report (OECD, 2020[2]) and detailed results in Part 2 (OECD, 2020[3]).

Republic. Other policy examples have been identified and could be considered in future work: small farmers scheme (Hungary, the Czech Republic, Italy and France); rural development programmes (Italy, France, the United Kingdom, Denmark, Hungary, and Sweden); as well as two examples on Australian policy reforms and deregulation of the dairy sector and the arable and sheep sectors.

The following analytical methods and tools are used conditional upon data availability and quality of statistical estimates in (OECD, 2020[2]):[4]

- Evolution over time of farms' characteristics and technology classes: descriptive statistical analyses and post-estimation tests using farm technology class estimates and performance indices per production type and country.
- Dynamics and patterns of class switching behaviour: probability analyses and post-estimation tests using the farm technology class membership probabilities per production type and country. Markov analysis of the evolutions of the class membership.
- Identification of the drivers that foster desirable class switches and potential links with policy measures: mixed-level multi-effects probit regression and bivariate random parameter selection regression techniques.
- Evaluation of policy effects on performances and class membership: treatment evaluation estimators (i.e. propensity-score-matching and difference-in-difference regressions) using the farm technology class membership probabilities per production type and country as well as related characteristics and indices. Identification of the marginal effect of policy measures on desirable class switches and performance.

All stages of this work have a significant policy relevance. Improving the targeting of policies requires good knowledge about the performance of different types of farms and the conditions that might trigger a switch from one performance class to another. Policies designed to improve farm productivity and environmental performance, should focus on solving the structural constraints that make farms less likely to improve their productivity and their environmental outcomes, and be targeted to those farms with potential to improve.

To analyse improvements in productivity, two groups of improvers are considered. First, a group of "permanent improvers", i.e. farms that switch to a more productive class from one year to the next year and remain there also in the subsequent year or improve even further (i.e. manage to switch again to a more productive class in the remaining period of their individual sample membership). Second, a group of "occasional improvers" which are farms that switch to a more productive class from one year to the next year but then fall back to a less productive class again.

Section 2 discusses the main findings and policy implications from the nine case studies on the dynamics of farm productivity performance and policy impacts. *OECD Food, Agriculture and Fisheries Paper* N°165 (Sauer et al., 2021[4])presents the detailed results of the case studies.

[4] The details of the methods are described in Annex A of *OECD Food, Agriculture and Fisheries Paper* N°165.

## 2. Main findings and policy implications

The analysis of the dynamic performance of farms in OECD (2021[4]) provides significant evidence on how the farms in the different case studies have evolved over time in terms of their performance in productivity and in other outcomes. The classification of farms in different classes according to their productivity performance allows a specific focus of the analysis on the dynamics of the productivity profiles of farms, and the main drivers behind the farms that succeed to improve their productivity in a permanent, resilient manner. The comparison across countries is relevant to analyse the impact of different policy environments or a policy change, as shown in the two policy examples. Furthermore, the analysis of the productivity dynamics is relevant for policy makers to understand the dynamic environment in which farms operate in each sector (in this case crops and dairy) and the evolution of the sector performance over time. This information and the knowledge of main drivers of productivity improvements at farm level is highly relevant for the design of policies that enable and enhance these drivers and target farms with more potential for productivity growth.

Table 1 highlights some of the findings in the seven case studies. The samples for crop farm case studies cover a similar period from between 20 and 30 years in Australia, France and the United Kingdom (England and Wales), to 8 recent years in Italy. This should be kept in mind when interpreting the results as a reflection of long-term adjustments (while, for example, in Italy they reflect medium to short term adjustments). The sample periods of the dairy farms case studies cover between seven and eleven recent years and should be interpreted as medium term dynamics.

### Table 1. Dynamics of farm performance in four crop case studies

A. Main results in crop case studies

| | Australia | France | Italy | United Kingdom |
|---|---|---|---|---|
| Period / No. of classes | 1989-2018 / 2 classes | 1989-2016 / 4 classes | 2008-2015 / 3 classes | 1995 -2017 / 3 classes |
| Productivity | Increased in both classes. Least productive reduced productivity between 2003 and 2018 (drought), diverging from Class 2 | Convergence in productivity across classes but reductions in highest productivity class | Slight increase on average, but decreased in most productive farm class | Increases for medium class. Slight reductions in highest productivity class with large number of new comers. |
| Environmental sustainability | Improved in both classes due to higher fuel efficiency | Divergence across classes, with increased sustainability except in highest productivity class | Maintained or increased for high productive classes but fell for least productive | Increasing divergence with some improvements in most productive class due to new comers |
| Other characteristics | Increase in innovation and diversification indexes in both classes | Only medium classes improve technical change, while diversification falls in all classes | Divergence in innovation, but convergence in diversification | Convergence in innovation, production intensity and diversification. |
| Improvers | More forward than backward switches, mostly permanent improvers. | Most improvers are occasional.<br>Larger and less family labour dependent | Most improvers are occasional.<br>Smaller and more family labour dependent | Improvers outweigh backward switches, and most are permanent |
| Drivers of improvers | Reduction in family labour, less use of fertilisers and<br>More contract farming | Family ownership, net investment, share of rented land and contract farming | More rented land, capital intensity and diversification | Net investment, less family labour, more chemical use |

**B. Main results in dairy case studies**

| | Czech Republic | Denmark | Norway |
|---|---|---|---|
| Period | 2005-2015 / 3 classes | 2010-2016 / 3 classes | 2005-2016 / 3 classes |
| Productivity | Increased for all farm classes, higher increase for most productive class | Slight increases across all classes | Larger increases in most productive class, divergence across classes |
| Environmental sustainability | Increased and convergence across classes, but least productive still lagging behind | Divergence across classes with deterioration in most productive class | Divergence across classes, deterioration in most productive class |
| Other characteristics | Increase in technical change and diversification across all classes. Divergence across classes on innovation and farm structures | Divergence in innovation and convergence in technological intensity. | Improvement in innovativeness with convergence across all classes. Reduced diversification and divergence across classes |
| Improvers | Increase in forward switches up to 2009, then decline, but the peak is mainly due to occasional non-permanent switches. | Outweigh backward switches, but significantly declined in the sample period. Permanent improvers are about half of all switches | Backward switchers outnumber improvers, which are mostly occasional (non-permanent) switches |
| Drivers of improvers | Few characteristics are statistically significant (small sample size) | More family labour and smaller herd size. More innovative and diversified | Smaller herd size, more specialised, young, female and off-farm income |

## Which are the different patterns of productivity dynamics for crop farms across countries?

Table 2 presents some indicators for the dynamics of farm classes as observed in the samples of the seven cases studies and as implied by their switching probabilities. The relative size of the most productive farm class increases over time in the four crop farm studies, but with very different scope of the adjustment. The relative size of the most productive class increases nine times in the United Kingdom and increased by 25 percentage points in Australia, while the increase in France was 15 percentage points and less than 1 percentage point in Italy (for the latter the much shorter sample period has to be considered).

The increase in productivity over time is common to all case studies, but particularly significant for Australia's most productive farms. This divergence between most and least productive classes observed for Australia does not happen in other countries. France and Italy experience convergence in productivity across farm classes, however, with reductions in the productivity of the most productive class. In the United Kingdom the change in the size of different classes is so radical that a reduction in the average productivity of the most productive farm class is not surprising given the incorporation of so many less productive farms during the sample period.

There seems to be a different pattern between Australia and the European countries in the case studies. Australia's crop farm structure dynamics tend to favour the most productive farm class which has also become more numerous; a small low productive class of farms also exists and does not catch up, particularly in recent years. Crop farms in France, Italy and the United Kingdom experience convergence across farms class performances with respect to productivity, but without significant productivity improvements on the frontier of the most productive classes. This pattern may reflect the given policy incentives in these three European countries subject to the European Union's Common Agricultural Policy, compared to more market oriented incentives by Australia's low support agricultural policy.

But the different patterns do not always respond to continental lines which mark the different policy environments. The changes across farm classes were largest in the United Kingdom followed by Australia and France, with very slow dynamics in Italy. Most of the inter class dynamics occurred in the first two decades in the sample period and then slowed down to result in more stable class shares. The current process of adjustment seems exhausted by the end of the period in both Australia and France, with very small additional long-term changes in the share of the most productive class (Table 2). In Australia, this

structural adjustment process seems to be affected by the extreme droughts in the last two decades. In France, the momentum of the main decoupling reforms in the 2000's could have been exhausted in more recent years. On the contrary, current dynamics of farm classes in the United Kingdom imply a pathway of continued improvement, which makes the agricultural policy decisions after Brexit crucial to enhance this process.

## Table 2. Dynamics of farm classes in seven case studies

Changes in the share of the most productive farm class (percentage points)

| Dynamic changes in the shares of farm productivity classes | | | | | |
|---|---|---|---|---|---|
| | Observed data in the sample | | Implied changes in Markov probability matrix* | | |
| | Period | Observed change in sample period | Short run change in 3 years | Long run change at convergence | Time for convergence (number of years) |
| Australia crops | 1989-2018 | +24.74 | -0.07 | -0.09 | 7 |
| France crops | 1989-2016 | +15.41 | +0.06 | +0.06 | 5 |
| Italy crops | 2008-2015 | +0.02 | -0.64 | -0.94 | 15 |
| UK crops | 1995-2017 | +90.80 | +10.13 | +31.30 | 58 |
| Czech dairy | 2005-2015 | -10.63 | -4.10 | -5.74 | 18 |
| Denmark dairy | 2010-2017 | +21.22 | +6.85 | +8.84 | 22 |
| Norway dairy | 2005-2016 | -9.38 | -1.62 | -2.44 | 18 |

Note: *Increase or reduction in the share of the most productive farm classes.

### Which are the different patterns of productivity dynamics for dairy farms across countries?

During the sample period of each of the dairy farms case studies, productivity increased in all three countries, but the pattern differed. In Denmark, the relative size of the most productive class largely increased by 21 percentage points, while most productive farm classes in Norway and the Czech republic reduced their share by 10 and 9 percentage points respectively (Table 2). Furthermore, if the current interclass dynamics remain in the future, the most productive class would continue to grow in relative terms in Denmark and would reduce its share in Norway and the Czech Republic.

The level of productivity across farm classes diverged over the sample period in the three country studies, implying larger differences in productivity between the most productive dairy farms and the least productive ones. The better performance dynamics in Denmark's dairy sector is associated with divergence on innovation but convergence on technological intensity across farms. The weaker performance of productivity dynamics across farm classes in dairy farms is associated with increased technical change and diversification across farm classes in the Czech Republic, and with a reduced diversification and improved and convergent innovativeness in Norway.

It is difficult to infer specific correlations with policies for these different patterns. The Czech Republic and Denmark show very different dynamics under the same Common Agricultural Policy. In Norway, the highly protected policy environment does not impede an increasing divergence between most and least productive farms, and the most productive farm class even shrinks in relative size over time.

### Does the policy environment influence different productivity performance dynamics?

The policy analysis in Anton and Sauer (2021[4])provides specific evidence on how different policy options can affect the dynamics of productivity. The methodology proves to be effective for the analysis of the EU decoupling reforms of 2003 and their relative impact on crop farms productivity. The study compares the

different decoupling options taken at that time by the governments of France (minimum decoupling allowed by the reform resulting on about 75% decoupling paid at historical rates) and England (full decoupling with hybrid regional-farm level rates[5]). The results of the analysis provide a clear positive answer to the question of whether the policy environment matters. The results are based on a comparable sample of 33 similar farms in England and France and need to be interpreted with care. The study finds a statistically significant impact of changing policy towards support that is not linked to specific production (decoupled). English farms in the sample were able to increase their productivity and to overtake the comparable sample of French farms in the post reform period up to 2008. The method applied allows to isolate the impacts of the policy differences and provides a strong message for the effect of agricultural policy reforms on productivity.

A slight but statistically significant negative impact of decoupling in England on the technical change of its crop farms during the period 2003 to 2008 has also been found. This seems counterintuitive at first glance, however, if we recall the different components of farm level productivity (i.e. technical change, technical efficiency, and scale efficiency) the findings are plausible. Productivity improvements are based on a combination of innovation effects, efficiency improvements with respect to technology handling (i.e. producing on the technology frontier) as well as optimising the scale of production. The results suggest that the productivity enhancing effects are primarily driven by efficiency and scale improvements and not by farms' adoption of new technologies (which would lead to technical change). The full decoupling approach in England effectively incentivised crop farms to further optimise their scale of crop production activities to decrease their average cost of production and hence, increase profitability. This is in line with expected microeconomic mechanisms triggered by more freedom under decoupled payments to adjust and allocate inputs and outputs in the farm. The results of the analysis of productivity classes in the United Kingdom (England and Wales) in Antón and Sauer (2021[4]) are consistent with this finding. Taking advantage of the opportunities of decoupling, crop farms in the United Kingdom apparently moved closer towards the optimal crop production frontier with a significant technical efficiency gain. The switches forward to more productive classes are more frequent among UK crop farms than the switches backwards and most of the switches forward are permanent rather than occasional. The opposite is true for French crop farms. While French farm dynamics hardly result in any further change in farm class shares, UK farms show an implicit positive evolution towards the most productive class 3 that seems to be sustained in the long term.

The same type of evidence on the positive and significant effects of decoupling on productivity has been reported by Kazukauskas, Newman and Sauer (2014[5]), one of the few papers studying productivity effects of decoupling in an ex post manner. Productivity gains are estimated to be the result of scale efficiency change or technical efficiency improvements. Efficiency improvements as a consequence of decoupling have also been found by (Carroll, Thorne and Newman, 2008[6]) for the Irish cattle rearing, cattle finishing and sheep sectors.

The same analysis is used to test for differences on other performance related and characteristics indicators. The test for a potential impact on farm structure, environmental sustainability, innovation and technology intensity did not produce statistically significant effects on these variables.

The results imply a clear impact on productivity, which is likely to play a significant role in the whole set of policy goals. However, the policy implications of these results have to be evaluated in the context of the multiple policy objectives of each country.

The methodology applied to analyse the impact of policy changes by comparing similar groups of farms in different countries is innovative and offers a potentially powerful tool, but its application is based in crucial

[5] This implementation model implied a middle way between flat regional rates per hectare and historical rates.

preconditions (e.g. sample size and control matches). The Czech dairy payments example shows its limitations when applied to small samples and policy changes that are not sufficiently significant, or when the policies themselves are not designed with a clear link to productivity performance. The dairy payments in the Czech Republic are partially decoupled since they are based on historical yields but current animal numbers. They also represent only a small part of the whole CAP policy package that applies also to farms in the country used for comparison (Estonia).

### Is productivity performance related to environmental performance?

Given the limitations of the environmental performance indicators that capture only a limited number of sustainability dimensions and also the constrained data availability, results on environmental performance have to be interpreted with caution. Moreover, there may be trade-offs between local and global sustainability in the case where lower productivity farms have a lower environmental footprint, but lower productivity leads to a global increase in agricultural area and associated land use change.

In general there is no clear pattern for the relationship between productivity and environmental sustainability. This holds both across farm classes with different productivity performances and also over time with a parallel or opposite evolution of productivity and sustainability. This lack of a clear pattern reflects that the increase in productivity can be based on different paths with respect to the use and combination of different inputs. With the right incentives, higher productivity can result from producing more output with less variable inputs that harm the environment. But different incentives could lead to increases in productivity that do not reduce the intensity of such inputs.

When comparing the different productivity farm classes for each country study, only in the case of the Czech Republic dairy farms in the most productive class do this farms also show the highest sustainability index. In the Danish dairy sector and in the UK crop sector (and also for crop farms in Australia at the end of the period) the opposite tends to be true: the less productive farms are the most environmentally sustainable. But the pattern productivity-sustainability is not clear in Italian and French crop farms.

Nor does the comparison of the time dynamics provide a clear pattern between productivity and sustainability. In the Czech dairy farms case study, the higher sustainability performance of the most productive farms is further enhanced over time. But in most of the other case studies, the least productive farm classes improve their relative environmental performance (crops farms in Australia, France and the United Kingdom, and dairy farms in Denmark). In Norway, the environmental performance of the most productive dairy farm class deteriorates over time, while its productivity significantly increases. On the other hand, moderate increases in productivity of the least productive dairy farms in Norway are compatible with increases in sustainability. In Australia, increases in productivity and sustainability indexes over time occurs for both most and least productive farm classes.

### What are the main drivers of permanent productivity improvers?

The analysis of the dynamics of productivity performance in the seven case studies in this paper provides also specific estimations of the main drivers for improvers, farms that have permanently or occasionally improved their performance and switched forward to other class. In general, the statistical significance of these drivers is larger for the permanent than the occasional improvers. This makes sense as an occasional change in the performance class has less meaning in terms of long-term structural change. The size of the sample of Czech dairy farms proved to be too limited to provide significant results. Despite the significance of the results for the rest of the country cases studies, there is not a clear pattern of drivers.

Across the farm structural variables, permanent productivity improvers tend to have less family labour (for Australian and Italian crop farms, but not in Danish dairy farms), lower land endowments (crop farms in France and dairy farms in Norway), and herd size in dairy (Denmark and Norway). On the contrary, in

Denmark larger family labour and land endowment is a positive driver for permanent improvers. In France, family ownership proves to be an important driver.

In several case studies, a higher use of inputs that are potentially harmful for the environment has a negative correlation with the probability of being a permanent productivity improver: fertilisers in Australia, chemicals in France and Italy, and stock density in Denmark. This provides an insight on possible synergies between more sustainable practices and the probability of improving productivity permanently. That said, organic farming is found to have a negative correlation with permanently improving productivity in Denmark.

Most innovation related variables have a positive correlation with the probability of being a productivity improver. This includes contract farming for Australian and French crop farms and for Danish dairy farms (but not for Norwegian dairy farms); rented land for crop farms in France and Italy; and net investment for English crop farms and Norwegian and Danish dairy farms.

The variables forming the technology index have varying correlations with the probability of productivity improvement in different cases studies. For instance capital intensity related variables are positively correlated for Italian crops and Norwegian dairy, but negatively correlated for Australian crop farms and Danish dairy farms.

Finally, among household characteristics, female farmers are found to be more likely to be permanently productivity improvers among UK crops farms and Norwegian dairy farms. In Norway, off-farm income is positively correlated with productivity improvers' probability for dairy farms.

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Comments are welcome and can be sent to tad.contact@oecd.org.