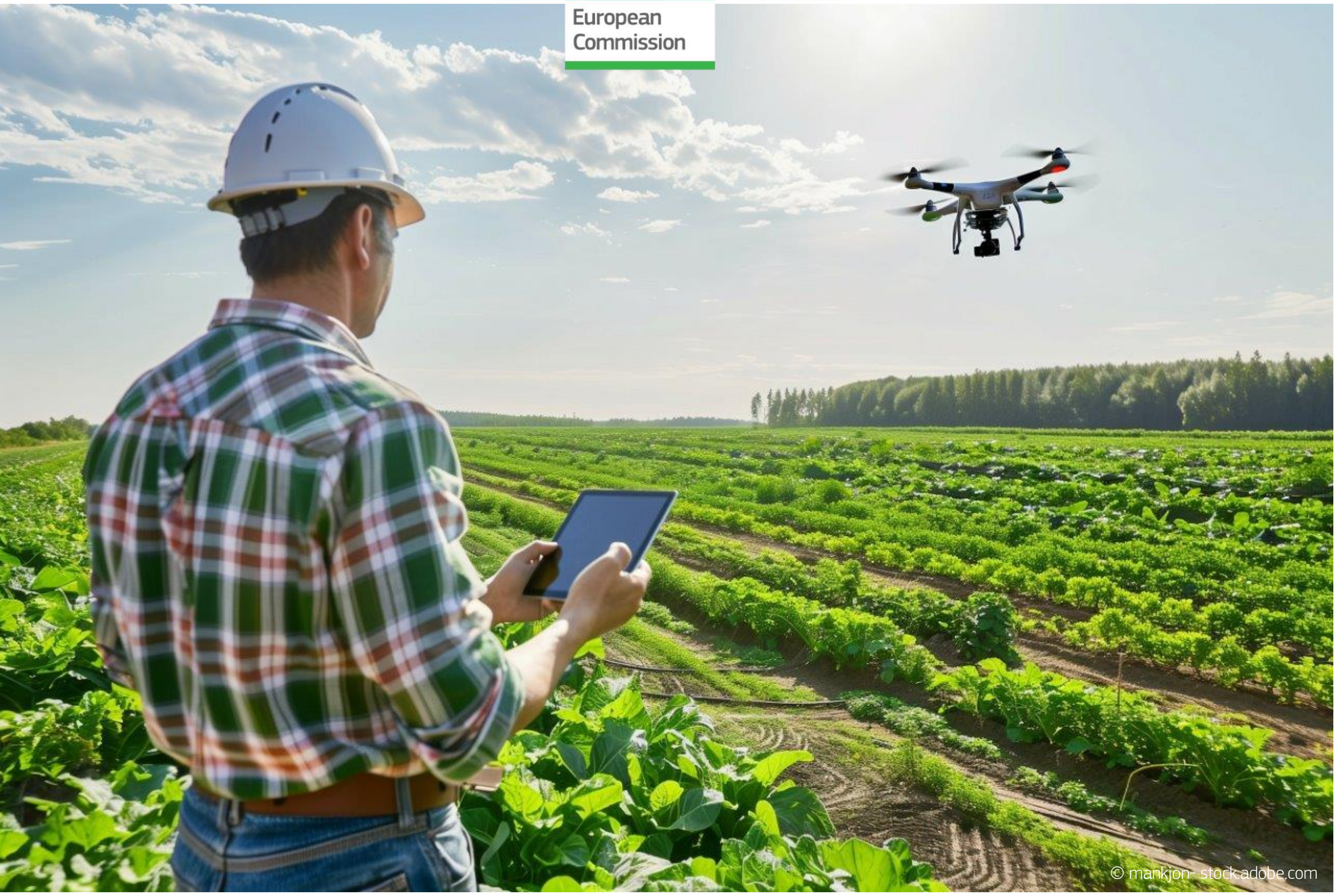


Analytical Brief N°5

MEASURING AGRICULTURAL PRODUCTIVITY

INSIGHTS INTO YIELDS AND TOTAL FACTOR PRODUCTIVITY IN THE EU

October 2024

Agriculture and Rural Development

CONTENTS

Introduction

This analytical brief highlights the increasing policy relevance of measuring productivity in the EU. Illustrating how agricultural productivity can be statistically measured, it shows the strengths and weaknesses of measuring trends in agricultural yields and the volume change of agricultural outputs and inputs, against the more complex yet condensed Total Factor Productivity (TFP), for EU agriculture. TFP allows a comparison between the evolution of aggregated agricultural output and the evolution of factors of production such as capital, labour, inputs and land. The analytical brief illustrates that TFP can be measured in different ways, by comparing the methodology used by the European Commission for this brief, and the method used by the Economic Research Service of the US Department of Agriculture (USDA ERS) in their International agricultural productivity series. The brief concludes with suggestions on how TFP could evolve into a more meaningful measurement that addresses the evolving policy objectives towards sustainability, resilience and competitiveness. Expanding the scope of TFP to include sustainability dimensions would allow obtaining an indicator which is more suited for measuring sustainable productivity growth.

HIGHLIGHTS

Agricultural productivity is a key objective of the Common Agricultural Policy (CAP), with an explicit reference in Article 39 of the Treaty on the Functioning of the European Union and featuring among the ten specific policy objectives of the CAP 2023-2027. President Von der Leyen identifies sustainable prosperity and competitiveness as one of the key priorities for the EU in her political guidelines for 2024-2029. Given the crucial importance of competitiveness for EU farmers, measuring agricultural productivity is a key indicator to assess this EU objective.

Assessing productivity through the evolution of yields provides an incomplete picture, as yield figures do not account for the use of inputs. While a consistent increase in yields has been observed for milk and certain cereals such as barley, it is impossible to assess productivity without accounting for changes in input use. A better assessment can be made by comparing agricultural output volumes (up 6.7% in 2023 from 2010 for the EU) with the use of intermediate inputs (up 3.8%). Nonetheless, this approach also has its limits as it does not account for other factors of production, notably land, labour and capital. These factors are reflected in the calculation of Total Factor Productivity (TFP). TFP for the EU depicts stable growth since 2010, increasing at an average annual rate of 0.6% and cumulatively 9.1% higher in 2023, with the highest growth rates in Eastern Member States. Based on TFP, the main driver of agricultural productivity growth is labour productivity, combined with mechanisation of EU agriculture, with investments in machinery and equipment compensating for the decline in agricultural labour. Comparing the EU TFP calculations for this analytical brief with those from the USDA-ERS reveal discrepancies attributable to methodological differences. As TFP does not explicitly to account for sustainability, its use for policymaking has shortcomings. This could be addressed by expanding the scope of TFP from measuring agricultural productivity to measuring sustainable productivity growth, through among others, the introduction of quality adjustments to inputs used, the internalisation of positive and negative externalities as well as the use of farm-level data. These developments would however require additional data collection and modelling efforts.

1. Why measure productivity?

Agricultural productivity is one of the five objectives of the Common Agricultural Policy set out in article 39 of the Treaty on the Functioning of the European Union[1]: "*to increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimum utilisation of the factors of production, in particular labour*".

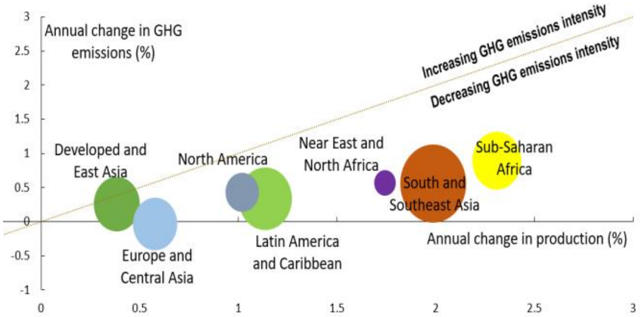
Agricultural productivity plays a key role for the competitiveness of EU farmers, which is one of the ten specific policy objectives of the Common Agricultural Policy 2023-2027[2]. Productivity growth is also an important instrument to reach the objectives set by the United Nations Sustainable Development Goal (SDG) 2 to end hunger, achieve food security and promote sustainable agriculture.

President Von der Leyen identifies sustainable prosperity and competitiveness as one of the key priorities for the EU in her political guidelines for 2024-2029. The strong linkage between productivity and competitiveness is also emphasized by the 2024 Report on the Future of European Competitiveness, as it clearly identifies that "*the core focus of a competitiveness agenda should be to raise productivity growth, which is the most important driver of long-term growth and leads to rising standards of living over time*[3]". These considerations also apply to EU agriculture and emphasize the role of productivity in enhancing its economic viability in the long run.

Moreover, the 2024 Strategic Dialogue Report[4] on the future of EU agriculture emphasizes that *"an economically, socially, and ecologically balanced system is less about maximising individual production factors, but rather about optimising benefits in terms of sustainability, resilience, profitability, and greater responsibility, not only for those involved in agriculture, but also for rural communities, civil society, and political actors"*. This suggests that the measurement of agricultural productivity is one of the many elements needed to fully understand the well-being of farmers and of rural communities. The last section of this brief includes potential options to further develop the concept of productivity with sustainability dimensions.

Especially in recent years, EU agriculture has faced several challenges linked to increased and volatile prices of inputs such as energy and fertilisers, and as extreme weather events linked to climate change impact production, measuring sustainable agricultural productivity appears increasingly important to assess whether farmers make the most efficient use of limited resources and remain within planetary boundaries. In this respect, graph 1.1. shows that the latest global projections by OECD-FAO depict that agricultural production will increase at a faster rate than the corresponding greenhouse gas (GHG) emissions, resulting in decreasing GHG emission intensity.

Graph 1.1 GHG emissions and emissions intensity from agriculture by world region, 2021-23 to projected 2033 levels



Source: OECD-FAO 2024-2033 Agricultural Outlook. The size of the bubbles corresponds to the level of agricultural GHG emissions in the baseline period 2021-2023.[5]

While graph 1.1 shows a trade-off between economic and environmental objectives, the most significant reductions in GHG emission intensities are expected from developing countries rather than from developed countries. According to the 2023 OECD Agriculture and Food Policy Review[6], the EU agri-food system has demonstrated its resilience and the ability to keep productivity growing, while achieving a partial decoupling of GHG emissions.

[1] Consolidated version of the treaty on European Union and the treaty on the functioning of the European Union (2016/C 202/01)

[2] EC DG AGRI (2019): CAP specific objectives explained – Brief No 2. "Increasing Competitiveness". https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-2023-27/key-policy-objectives-cap-2023-27_en#documents

[3] https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en

[4] https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/main-initiatives-strategic-dialogue-future-eu-agriculture_en

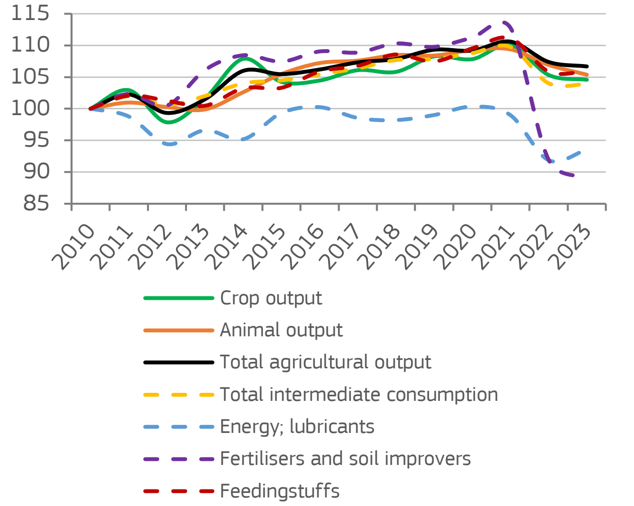
[5] https://www.agri-outlook.org/

[6] OECD (2023), Policies for the Future of Farming and Food in the European Union, OECD Agriculture and Food Policy Reviews, OECD Publishing, Paris, https://doi.org/10.1787/32810cf6-en.

2. Evolution of EU agricultural outputs, inputs and yields

The evolution of EU agricultural outputs and inputs is shown in graph 2.1: while agricultural output has grown by 6.7% in 2023 compared to 2010, it declined for two consecutive years since 2022. Over the same period, total use of inputs has increased by 3.8%, with very significant decreases for fertilisers and energy use, driven by the surge in energy prices triggered by the 2022 war in Ukraine. In 2023 the sector used 11% less fertilisers and 6.5% less energy compared to 2010. Feed use has instead increased over time, being 5.9% higher in 2023 compared to 2010.

Graph 2.1 – Evolution of EU-27 agricultural output and input costs - index 2010 = 100

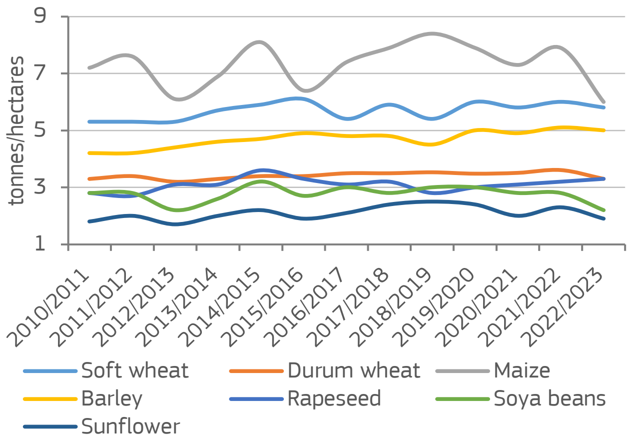


Source: Eurostat Economic Accounts for Agriculture, values at constant prices. Online data code: aact_eaa03

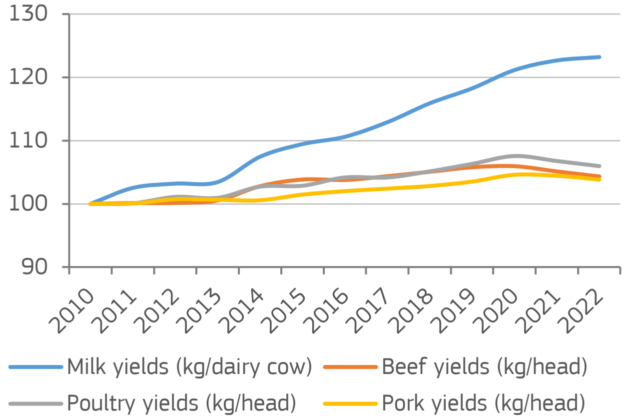
Graph 2.1 suggest that EU agricultural output grew faster than the increase in the intermediate inputs used for production but lacks additional elements that need to be accounted for a more complete measurement of agricultural productivity. It does not consider the use of other factors of production such as labour inputs, hectares of land used and consumption of fixed assets such as machinery and equipment. For this reason, a more refined indicator of agricultural productivity is required.

A metric which is commonly used to analyse the evolution of agricultural productivity is agricultural yield. The advantage of such indicator is that it is a simple ratio of physical measurements: tonnes of product per hectare of land, or kilograms per livestock head, hence it is immediately intuitive. The disadvantage of using yields as proxies for productivity is that they cannot be aggregated into a single value for agriculture as a whole, since they are necessarily linked to their respective sectors: yields of cereals are different than those for oilseeds, while animal yields are entirely different in magnitude depending on the type of livestock.

Graph 2.2 – Evolution of yields for a selection of cereals and oilseeds for the EU-27



Graph 2.3 – Evolution of milk and meat yields (kg per head) in the EU-27 - index 2010 = 100



Source: EU agricultural markets short-term outlook – autumn 2024

An overview of the evolution of yields in the EU is provided by graphs 2.2 and 2.3. The first graph shows the evolution of the yields for the main cereals and oilseeds cultivated in the EU: the most noticeable increases are observed for soft wheat (11% increase compared to the marketing year 2010/2011) and barley (17% increase over the same period). A strong interannual volatility is also observable, especially in the case of maize yields. The 2024 OECD-FAO Agricultural Outlook shows that while the EU has high yields for wheat compared to other world regions, maize and soya bean yields are significantly higher in North America, while for other oilseeds Southeast Asia has better yields due to more favourable agroclimatic conditions.

Graph 2.3 shows instead the evolution of yields for milk and meat products. It is immediately visible how milk yields have significantly increased (23% over the period considered), while yields of meat products increased much less, reaching a growth between 4% to 6% over the same period. Overall, yields are useful complementary information to complete the picture of agricultural productivity in the EU and they can be used for cross-country and cross-regional comparisons, However, yields are a measure of partial productivity, since the output is evaluated in relation to a single factor of production, and can only be analysed for individual commodities.

3. Total Factor Productivity

Total Factor Productivity (TFP)[7] is a ratio that relates the change in aggregate output against the change in the factors to produce them. The main inputs typically considered for agricultural productivity analysis are land, labour, capital and intermediate inputs (e.g. feed, energy, fertilisers etc). In this brief TFP is expressed as an index with 2010 as a base year to compare agricultural productivity over time. A value higher than 100 implies that the agricultural output has grown more than the four inputs considered in the calculation, hence TFP corresponds to the joint effect of many productivity drivers other than those explicitly accounted, including new technologies, efficiency gains, economies of scale, managerial skill, changes in the organization of production but also agricultural policies. Fundamental to the management of policies and improvements in productivity is the understanding of the trends of the drivers.

TFP is currently used in the Performance Monitoring and Evaluation Framework (PMEF) of the 2023-2027 Common Agricultural Policy as a context indicator (C.29) and as an impact indicator (I.6) linked to the objective of increasing farm productivity[8].

In this brief, the various agricultural outputs and inputs are aggregated as weighted averages of their changes in quantities, with weights corresponding to their value in real terms, with some corrections applied to reflect opportunity costs sustained by farmers. TFP is calculated as a Fisher Index, that is a geometrical mean between an arithmetic mean (Laspeyres Index) and a harmonic mean (Paasche Index) to compensate the biases of the latter two methods. Statistical data comes mainly from Eurostat Economic Accounts for Agriculture, with the benefit of providing annual time series of the economic performance of EU agriculture with detailed output and cost types and with remarkable timeliness. Looking at the factors of production considered in the calculation, labour inputs are measured in terms of Annual Working Units (AWU)[9], including salaried and non-salaried workforce. Capital input is proxied with the change in volume terms of Fixed Capital Consumption. Land input is measured in terms of change of Utilized Agricultural Area (UAA). Finally, intermediate inputs are considered as quantity changes of intermediate consumption accounts. For additional information on sources and methodology, refer to the Annex.

An additional advantage provided by Total Factor Productivity is the possibility to obtain Partial Factor Productivities, that is relating the evolution of output vs. a single type of input, to provide additional complementary insights into EU agricultural performance.

Despite its analytical potential, TFP is not a straightforward indicator of productivity[10]: First because, depending on the methodology used, it may capture simultaneously many unknown elements that cannot be explained with the evolution of factors of production. For this reason, it has been negatively labelled by economists as "a measure of our ignorance"[11]. It may be influenced by omitted variables, such as environmental variables[12,13]. The calculation method in this brief smoothens the effects of interannual volatility on TFP with the use of three-year moving average, but this correction would not be sufficient for more systematic and recurrent weather events.

It is nonetheless important to monitor Total Factor Productivity since according to the OECD[14] it has been an important driver of global agriculture production, especially in the two decades from 1990 to 2010. However, global TFP growth in agriculture has been slowing down in the last decade of 2010s, and if this slowdown continues, there could be significant consequences in terms of food prices and food insecurity, as global agricultural production would not be able to adapt to population growth and climate change. According to the OECD-FAO

7 Sometimes referred to as "Multifactor Productivity".

8 For more information on the CMEF and the PMEF of CAP: https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cmef_en

9 One AWU corresponds to the input, measured in working time, of one person who is engaged in agricultural activities on an agricultural unit on a full-time basis over an entire year.

10 For an overview of the methodological limitations of TFP, see Murray and Sharpe (2016): "Partial versus Total Factor Productivity: Assessing Resource Use in Natural Resource Industries in Canada". Prepared for the Smart Prosperity Institute.

11 Quote by Moses Abramovitz in its 1956 paper "Resource and Output Trends in the United States since 1870".

12 Although in economic literature there have been attempts to further model TFP to better model and isolate technological growth, for example the work done by Romer to model long-run growth with knowledge as an input in production. Romer, Paul M. 1986. "Increasing Returns and Long-Run Growth." Journal of Political Economy 94 (5): 1002–37.

13 Miles Parker (2023): "How climate change affects potential output". Published as part of the ECB Economic Bulletin, Issue 6/2023.

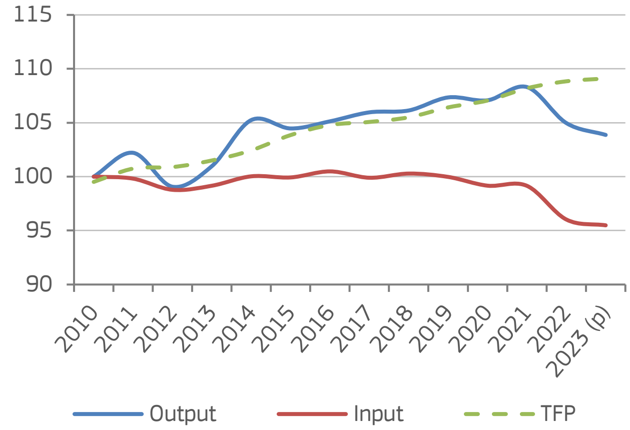
14 Bureau (INRAE) and Antón (OECD): Agricultural Total Factor Productivity and the Environment: A Guide to Emerging Best Practices in Measurement. OECD Food, Agriculture and Fisheries Paper May 2022 n°177.

2022-2031 Outlook, to achieve the Zero Hunger SDG target while simultaneously keeping agricultural emissions on track to reach the Paris Agreement targets, average global agricultural productivity would need to increase by 28% over the next decade, which is more than triple the increase recorded in the last decade[15]. In this context, it is important to estimate TFP beyond primary agriculture and measure the overall efficiency of the food value chain, looking at the productivity of downstream processes, where better storage, more efficient logistics, reduction of food waste and loss, could all help to reduce food insecurity.

3.1 TFP in the EU and in Member States

Graph 3.1 shows the overall change over time of the aggregated EU agricultural output, input and Total Factor Productivity. While output volumes have generally grown since 2010 compared to agricultural inputs that remained generally stable until 2021, in 2022 both quantity indices have dropped in a similar manner, reflecting the fact that the use of lower amounts of inputs (such as energy and fertilisers) had an impact on overall agricultural production. Nonetheless, total factor productivity has shown a stable evolution over time, growing annually at an average rate of 0.6% and being 9.1% higher in 2023 than 2010.

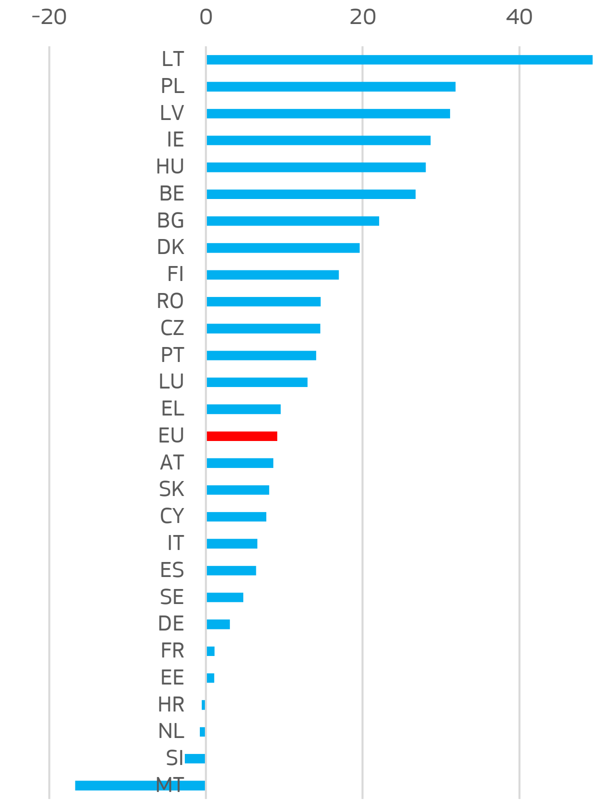
Graph 3.1 – Evolution of EU-27 agricultural output in volume, aggregated inputs (labour, capital, intermediate inputs and land) and Total Factor Productivity (TFP) three–year moving averages - index 2010 = 100



**2023 is provisional as land data is missing.*
Source: DG AGRI calculation based on Eurostat Economic Accounts for Agriculture.

The same indicator at country level returns a different picture, with Eastern Member States such as Lithuania, Poland and Latvia achieving a growth of agricultural productivity over 30% between 2010 and 2023, while on the other end of the ranking, Slovenia and Malta show negative productivity changes, with Malta having a significant reduction of 16% between 2010 and 2023. However, the calculation for Total Factor Productivity in this brief is not particularly robust for small countries, since large changes in volume stemming from small numbers could return very large TFP changes. Despite this, Maltese agricultural output has been declining significantly in volume terms in most recent years (-21% in 2023 compared to 2010), particularly for crops (-32%).

Graph 3.2 – Change in TFP from average 2010-12 to average 2021-23* across EU Member States - %



**2023 is provisional as land data is missing.*
Source: DG AGRI calculation based on Eurostat Economic Accounts for Agriculture.

The performance of Member States shown in graph 3.2 is measured in terms of productivity growth, but the TFP indicator in this brief does not allow to derive their respective productivity levels. EU countries ranking on the top are not necessarily the most productive. In particular, Eastern Member States that joined the EU after 2004 have generally seen a larger productivity growth than other Member States, also because of the increase in labour productivity and more recent investments and Common Agricultural Policy support towards agricultural modernisation[16].

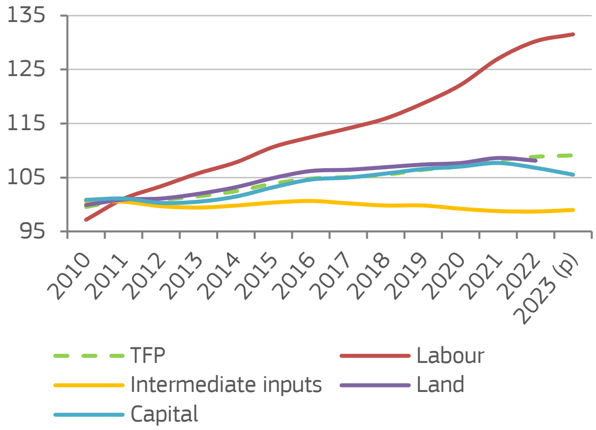
3.2 Insights from partial factor productivities

Graph 3.3 completes the overview of EU agricultural productivity by including the four partial factor productivities, that is the evolution of agricultural output against the change in units of labour, land, intermediate inputs and capital taken individually.

[15] OECD/FAO (2022), OECD-FAO Agricultural Outlook 2022-2031, OECD Publishing, Paris, https://doi.org/10.1787/f1b0b29c-en

[16] For an overview of the role of financial public support in Central and Eastern European countries, see Czubak, Pawłowski & Sadowski (2021): Outcomes of farm investment in Central and Eastern Europe: The role of financial public support and investment scale, Land Use Policy, Volume 108 https://doi.org/10.1016/j.landusepol.2021.105655

Graph 3.3 – Evolution of EU-27 Total Factor Productivity (TFP) and partial productivities of labour, land, intermediate inputs and capital – three-year moving averages - index 2010 = 100

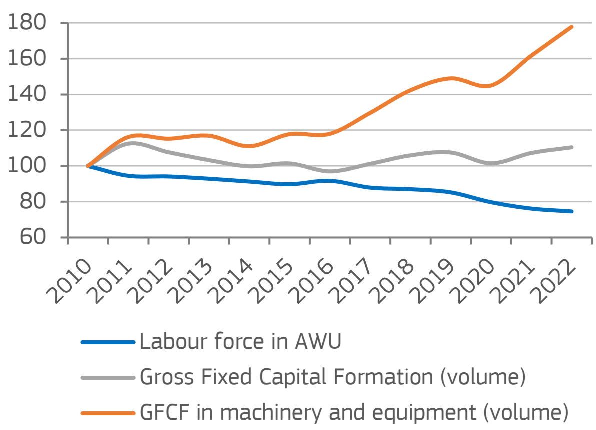


**2023 is provisional as land data is missing.*
Source: DG AGRI calculation based on Eurostat Economic Accounts for Agriculture.

The most noticeable upward trend among the partial productivity measures is **labour productivity,** i.e. the change of agricultural output related to the change in the number of Annual Work Units (AWU). This indicator shows that the EU increased its agricultural production with significantly less labour. The absolute number of AWUs have dropped from 10.3 million units in 2010 to 7.6 million units in 2023 (source: Eurostat, aact_ali01). The reduction is entirely from the non-salaried workforce (farm holder and members of his/her family) rather than salaried workforce, whose level remained generally constant at around 2.3 million units over the last 13 years. This seems to indicate that certain labour types have been replaced with investments in better agricultural machinery and equipment to achieve a growing output with less labour input. The evolution depicted by labour productivity accounts for quantity, but not for quality of work: modern agricultural machinery and equipment requires a more skilled workforce, hence this evolution in agricultural skills would be captured by output increase and TFP, but not directly measured through labour productivity.

Graph 3.4 compares the evolution of labour force in AWUs against the change in Gross Fixed Capital Formation (GCFC), which measures the acquisition of fixed assets by EU farmers, measured in volume terms. While these elements are not sufficient to prove the existence of a causal link between the acquisition of machinery and the reduction in labour force observed in the EU agricultural sector, it is indicative of a continuing, progressive mechanisation of EU farming.

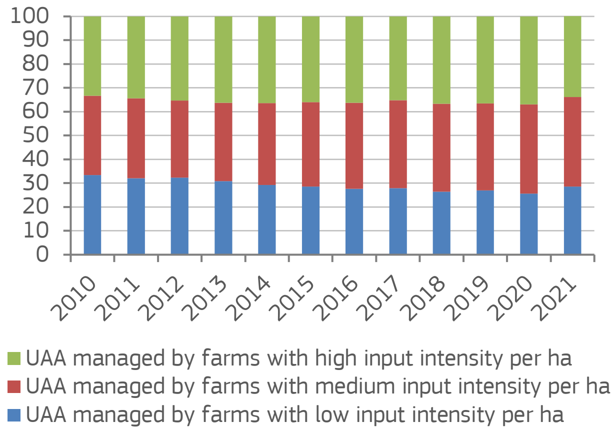
Graph 3.4 – Change in EU-27 agricultural labour force in Annual Work Units (AWU), Gross Fixed Capital Formation (GCFC) in Agriculture and GFCF for agricultural machinery and equipment – index 2010 = 100.



Source: DG AGRI calculation based on Eurostat Economic Accounts for Agriculture.

Land productivity - the second partial productivity indicator - increases over the period considered, with an evolution that closely follows that of TFP. The evolution of utilised agricultural area (UAA) in the EU has been generally stable since 2010, fluctuating around 161 million hectares (source: Eurostat, apro_cpsh1). It is relevant to assess whether the increase in land productivity in the EU is due to a growing intensification of agriculture.

Graph 3.5 – Shares of UAA managed by small, medium and high intensity farms in the EU - %



Source: DG AGRI calculation based on FADN and Eurostat data.

To address this question, a useful perspective is provided by the context indicator 34 of the Performance Monitoring and Evaluation Framework of the CAP: Farming Intensity. Graph 3.5 shows the evolution of the shares of UAA managed by farms with low, medium and high input intensity[17]. Under the assumption that an increased input intensity would lead to higher yields, the indicator shows that over the share of UAA managed by farms with high input intensity has increased from 33% in 2010 to above 36% afterwards, falling again to around 34% in 2021. The share of UAA managed by farms with medium input intensity has increased the most, from 33% in 2010 to almost 38% in 2021. Finally, the share of UAA managed by low intensity farms dropped from 33% to around 29% in 2021. Therefore, from this indicator it can be deduced that, among other factors, land productivity could also have been driven by a shift in the management of agricultural areas by farms with low input intensity to medium input intensity, rather than being driven by an increase in land managed by farms with high input intensity.

Capital productivity follows a similar pathway as TFP, with a decline in 2022 and 2023. The increase in mechanisation and automation in EU agriculture to replace labour could explain why its growth is not as prominent as labour productivity, although the growth until 2021 could be explained by positive economies of scale that led to more agricultural output than their utilisation. A possible interpretation for the decline in the last two years could be the 2022 energy crisis, since EU agriculture machinery uses mostly fossil fuels. The increase in energy costs could have led to a lower utilisation and to a lower output than in previous years.

[17] The areas are classified under low, medium or high input intensity according to the terciles of the distribution of their input intensity. For more info on the methodology, see https://agridata.ec.europa.eu/Qlik_Downloads/InfoSheetEnvironmental/infoC33.html

Finally, **intermediate input productivity** is basically stationary over time. The most likely reason is that this is a category that includes feed, fertilisers, plant protection products and energy which represent variable costs whose utilisation would be most correlated with agricultural output. To obtain a visible change for this indicator, certain intermediate inputs used in agriculture should be switched with another productivity driver to a sufficiently large scale to be visible at country level. While for example, the use of mineral fertilisers could be reduced with the use of organic ones, or by implementing environmentally friendly farming practices or technologies such as precision farming, these alternatives are not yet implemented to such a scale to be able to observe an upward trend at EU level.

4. Alternative measurements of TFP

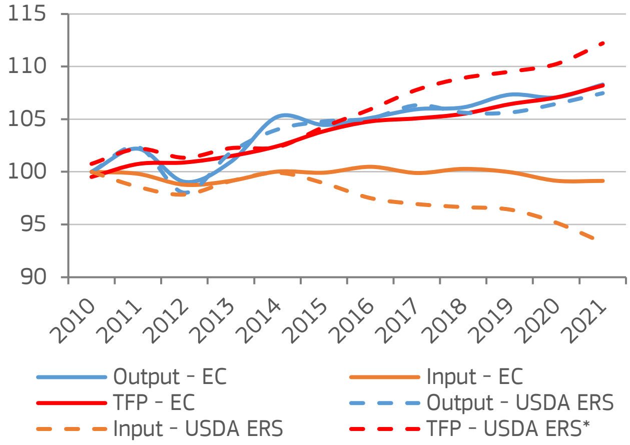
TFP can be measured in different ways. A notable source of Agricultural TFP indicators is offered by the International Agricultural Productivity dataset of the US Department of Agriculture, Economic Research Service (USDA ERS). This dataset provides estimates of TFP growth (not levels) for 179 countries since 1961, so it is a very comprehensive source for long term evolution of agricultural productivity across the globe[18]. Aside from the source of primary data used (Eurostat vs FAOSTAT mainly) there are methodological differences between the TFP calculation for this brief and USDA-ERS TFP, notably those related to[19]:

- **Calculation:** TFP for this brief is calculated as a Fisher Index, i.e. a geometric mean of the ratio of the Laspeyres and Paasche Indexes of the outputs and inputs. USDA-ERS uses the Growth Accounting method, obtaining TFP as a difference between the value-share weighted growth of agricultural aggregated output and input.
- **Output:** TFP for this brief includes crop and animal output, as well as secondary and transformation activities performed by the farms. USDA-ERS considers crop and animal output and includes aquaculture.
- **Weighting:** USDA-ERS uses constant shares for output and input for each decade. TFP for this brief uses yearly shares (Economic Accounts for Agriculture in real terms).
- **Labour:** the calculation used in this brief uses Annual Work Units (AWUs), which are also different across Member States, while USDA-ERS uses the number of economically active people working in agriculture, hence considering full time workers and seasonal workers in the same manner.
- **Land:** TFP for this brief uses Utilised Agricultural Areas for land inputs. The USDA-ERS gives different weights to introduce land quality elements, distinguishing by rainfed croplands, permanent pastures and irrigated croplands, with higher weight given to irrigated cropland than pastures.
- **Capital:** TFP for this brief uses fixed capital consumption, while the USDA-ERS uses the value of agricultural stock using the Perpetual Inventory Method, deriving its value from Gross Fixed Capital Formation (GCFC) and depreciation.
- **Intermediate consumption:** USDA-ERS uses mainly animal feed and fertilisers volumes to derive an index for material input use. TFP for this brief uses the intermediate inputs from Eurostat Economic Accounts of Agriculture covering additional inputs such as energy, plant protection products, seeds but also services purchased by farmers, such as veterinary expenses.

[18] https://www.ers.usda.gov/data-products/international-agricultural-productivity/

[19] For additional information on UDSA-ERS methodology, please consult: https://www.ers.usda.gov/data-products/international-agricultural-productivity/documentation-and-methods/

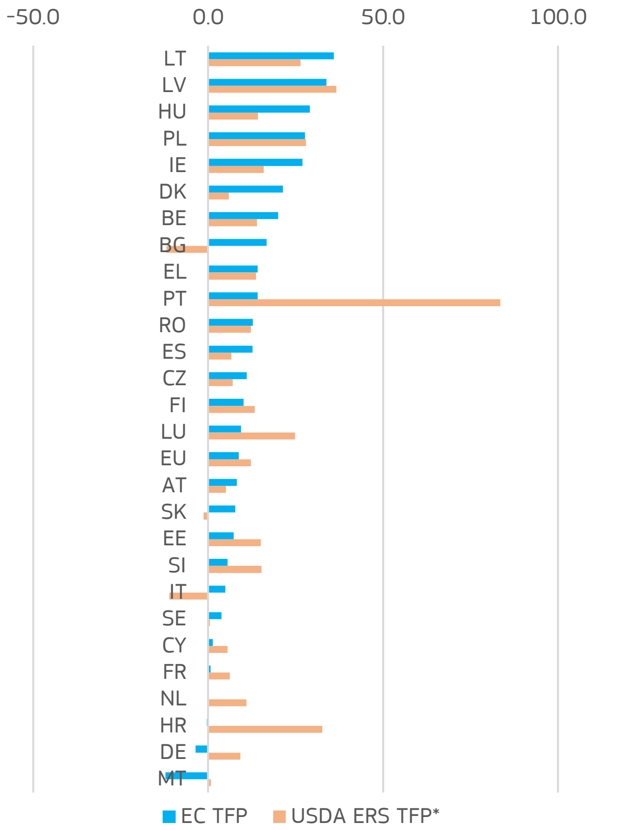
Graph 4.1 – Evolution of EU-27 agricultural output in volume, aggregated inputs (labour, capital, intermediate inputs and land) and Total Factor Productivity (TFP) presented in this brief (EC TFP) against the calculations by the USDA-ERS– -three year moving averages - index 2010 = 100



**USDA-ERS data is converted into base year 2010 and smoothed with a 3-year average to be comparable with the calculations of the European Commission*

Source: DG AGRI calculation based on Eurostat Economic Accounts for Agriculture and USDA-ERS data.

Graph 4.2 – Change in TFP from 2010 to 2019-21 (average) by Member States (EC TFP) against the calculations by the USDA-ERS – three-year average - %



**USDA-ERS data is converted into base year 2010 and smoothed with a 3-year average to be comparable with the calculations of the European Commission*

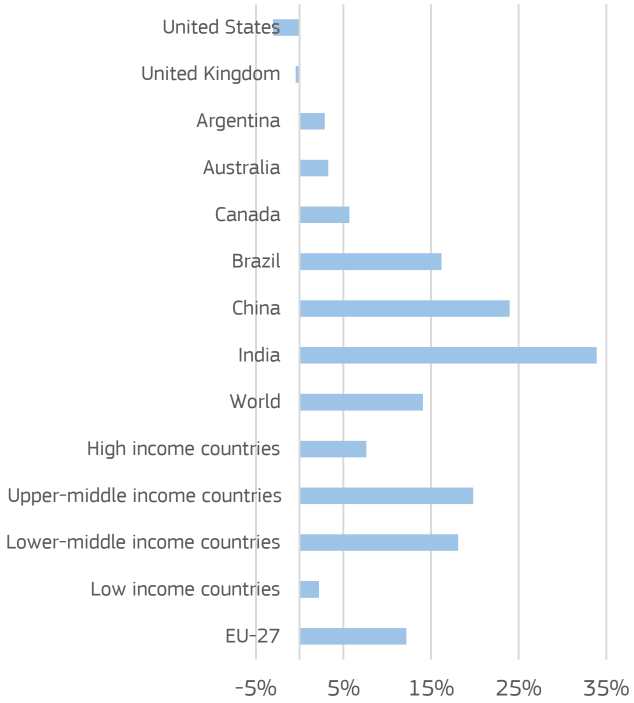
Source: DG AGRI calculation based on Eurostat Economic Accounts for Agriculture and USDA-ERS data.

The difference between the two sources is shown in graph 4.1. The output trend is generally similar across the two sources, while the aggregated input calculated by USDA-ERS diverges to a lower value from 2015 onwards, resulting into a TFP which is four percentage points higher than what is reported for the EU in this brief. The reason for this divergence in input can be mainly attributed to the difference in calculating labour and intermediate consumption inputs. By using headcounts instead of AWUs, USDA-ERS labour input between 2010 and 2021 falls by 27% compared to the AWUs time series from Eurostat, which returns a 24% reduction over the same period. Looking at the two trends for intermediate inputs, USDA-ERS returns a more nuanced increase in inputs, by 1% between 2010 and 2021, compared to a 11% increase over the same period using the Eurostat sources. The reason for this divergence is probably due to the coverage of inputs, since TFP for this brief includes all intermediate inputs, while USDA-ERS focuses only on feed and fertilisers.

The divergence between the two sources is more prominent when looking at the results at country level: while in some cases the two return similar levels (particularly for Latvia, Poland, Greece, Romania) but in other cases the two tend to be significantly divergent both in terms of directions and magnitude.

4.1 International TFP comparisons

Graph 4.3 – Change in TFP from 2010 to 2019-21 (average) by country income groups, world and selected countries - %



Source: DG AGRI calculation based on USDA-ERS data.

Bearing in mind the methodological differences across sources, USDA-ERS data allows to compare EU agricultural productivity with other countries and regions in the world. As shown by graph 4.3, lower and upper middle-income countries show the highest increases in agricultural TFP growth over the last decade (+18% and +20% respectively) while high income countries show a lower growth rate of +7.6%. In comparison, low-income countries struggled with increasing their agricultural growth, recording only an increase of 2.2% over the considered period. While the EU recorded a TFP growth higher than the high-income group, countries such as India, China and Brazil have shown a more significant increase in productivity over the period considered (+34%, +24% and +16% respectively).

5. Way forward

Monitoring agricultural productivity is of fundamental importance for the EU Common Agricultural Policy given its interlinkages with farm competitiveness, famers' income, food security and sustainability of EU agriculture.

Total Factor Productivity provides a useful framework to assess the evolution of technical and technological growth in agriculture, by quantifying the growth driven by factors beyond land, capital, labour and intermediate inputs. In addition, partial factor productivities complement the narrative by showing how agricultural output evolves over time per unit of input.

Even with these advantages, at the current stage the residual nature of Total Factor Productivity in agriculture does not allow to distinguish between the effects of agricultural technologies, farming practices, research & development, knowledge sharing initiatives and policy measures. It is therefore difficult to understand through Total Factor Productivity alone which measures could be more effective to revert the trend of slow-down in EU productivity growth which has been observed in the last decade. In addition, Total Factor Productivity is derived from neoclassical economic growth theory, and it does not explicitly include environmental variables for more fine-tuned sustainability analyses, which has become an important aspect for policy analysis.

In recent years, the integration of such elements has paved the way towards the concept of "Environmentally Adjusted TFP" as a more suitable indicator to reflect the efforts made to achieve **sustainable productivity growth** in agriculture[20].

Further expansions of Total Factor Productivity, especially to include broader sustainability aspects, are feasible in the medium term, depending on the availability of additional data sources. The following elements should be considered, some of which are going to be further analysed through a methodological review of the calculation of Total Factor Productivity of EU agriculture by the EC Joint Research Centre:

- **Introduction of quality adjustments**: the calculation of Total Factor Productivity relies on the use of quantity indices for output and inputs, with the results of rewarding the production of more with less, rather than producing a better agricultural output with a more sophisticated use of inputs. This requires the introduction of quality elements: for example, the USDA-ERS introduces quality elements for land in their TFP series, rewarding irrigated croplands with higher weights than rainfed croplands and pastures. Similar adjustments could be introduced to reflect new realities of agricultural production, e.g. by rewarding organic production, the maintenance of organic soils, or by providing a higher importance to skilled labour to reflect the skillset of future agricultural workers. These elements, when reflected by statistics with the desired coverage and timeliness, could provide a better linkage of TFP to multiple EU policies and policy objectives.
- **Internalisation of externalities:** the additive nature of TFP allows for the inclusion of the effects of positive and negative externalities in the calculation of agricultural productivity, covering undesired outputs such as greenhouse gas emissions and environmental pollution, but also desired outputs e.g. on biodiversity and preservation of rural landscapes. While this is a very promising pathway towards the measurement of sustainable productivity growth in EU agriculture, it poses two types of methodological challenges: first, statistics about the externalities of agriculture must be available, while in practice certain environmental impacts might be only measured through proxies (e.g. the Farmland Birds Index as a proxy for biodiversity measurement) or the available data might not be granular enough to capture the effects of all mitigation measures that are supported by the Common Agricultural Policy, as it is the case of Greenhouse Gas emissions in agriculture. Even when such data is available, it needs to be integrated into the TFP frame via weighting that would require a monetarisation of the externalities. Since these would not be traded in a market, their monetarisation would require the quantification of "shadow prices" which are often calculated with further assumption and data requirements.
- **Farm level data:** TFP at national level only allows to obtain macroscopic considerations about productivity trends in agriculture. A regional or even a farm-level scale indicator would allow to derive more in-depth evidence about the link between productivity, farming practices, land features and agroclimatic conditions[21]. The conversion from the Farm Accounting Data Network (FADN) to the **Farm Sustainability Data Network (FSDN)[22]**, with the collection of additional environmental and social indicators to the database of microeconomic and accountancy data represents a useful statistical source to exploit for policy analysis of agricultural productivity and sustainability.
- **International cooperation:** there are plenty of methods and data collections that are or can be used to expand TFP into a measure of sustainable productivity growth. However, an internationally agreed approach, driven by exchanges of best practices, would allow to consolidate a methodology for monitoring progresses and suitable cross-country comparisons. The OECD Network of Total Factor Productivity and the Environment appears to be the appropriate international reference for these co-ordinated efforts.

Further reflections on the possible evolution of the indicator to combine sustainability and productivity dimensions are needed to provide added value in future policy making discussions in an efficient and informative manner.

[20] For a review of methods, see OECD work on environmentally adjusted multifactor productivity: https://www.oecd.org/en/publications/environmentally-adjusted-multifactor-productivity_9096211d-en.html

[21] See for example Baldoni & Esposti. (2020). Agricultural Productivity in Space: an Econometric Assessment Based on Farm-Level Data. American Journal of Agricultural Economics. 103.

[22] Regulation (EU) 2023/2674 of the European Parliament and of the Council of 22 November 2023 amending Council Regulation (EC) No 1217/2009 as regards conversion of the Farm Accountancy Data Network into a Farm Sustainability Data Network.

6. Methodological annex

In this brief, Total factor productivity (TFP) compares total agricultural output relative to the total aggregated input used for its production, expressed as a ratio between the two. Both aggregated output and input are expressed in terms of volume indices (i.e. at constant prices), therefore the indicator measures TFP change over time, but not the productivity levels.

The changes in output and input volumes are measured against the base year 2010 and whose value is set to 100. Output and input indices are calculated as weighted averages of changes in produced quantities and in input quantities respectively, where the weights are represented by the production value in real terms of the various products and the expenditure for each of the four considered production factors (intermediate inputs, land, labour, capital).

TFP reflects output per unit of some combined set of inputs: an increase in TFP reflects a gain in output quantity which is not originating in from an increase of the four inputs considered in the calculation (land, labour, intermediate inputs[23] and labour). As a result, TFP reveals the joint effect of many factors including new technologies, efficiency gains, economies of scale, managerial skill, and changes in the organization of production.

TFP is calculated as a Fisher Index, which corresponds to a geometric mean between a Laspeyres Index and a Paasche Index. A Laspeyres index is an arithmetic mean of yearly volume changes with weights referring to the year before, while a Paasche index is a harmonic mean with weights referring to the current year. Since both means tend to be biased, the Fisher Index is used to correct and balance the two.

In formula, the TFP Laspeyres index (L) corresponds to:

$$TFP^{t}_{t-1_L} = \frac{OUTPUT^{t}_{t-1}L}{\mathrm{INPUT}^{t}_{t-1}L} =$$

$$\frac{\left(\sum_{j=1}^{n} \frac{q_{j,t}}{q_{j,t-1}} * w_{j,t-1}\right) / \left(\sum_{j=1}^{n} w_{j,t-1}\right)}{\left(\sum_{k=1}^{4} \frac{i_{k,t}}{i_{k,t-1}} * x_{k,t-1}\right) / \left(\sum_{k=1}^{4} x_{k,t-1}\right)}$$

While the TFP Paasche index (P) is equal to:

$$TFP^{t}_{t-1_P} = \frac{OUTPUT^{t}_{t-1}P}{\mathrm{INPUT}^{t}_{t-1}P} =$$

$$\frac{\left(\left(\sum_{j=1}^{n} \frac{q_{j,t-1}}{q_{j,t}} * w_{j,t}\right) / \left(\sum_{j=1}^{n} w_{j,t}\right)\right)^{-1}}{\left(\left(\sum_{k=1}^{4} \frac{i_{k,t-1}}{i_{k,t}} * x_{k,t}\right) / \left(\sum_{k=1}^{4} x_{k,t}\right)\right)^{-1}}$$

where q_{jt} and i_{kt} are respectively the quantity of output *j* and input *k* at time *t* (for a total of four inputs), while w_{jt} and x_{kt} are the corresponding weights.

The volume indices published by Eurostat are Laspeyres indices where changes in volume are measured using the prices for the preceding year. They correspond to the ratios $q_{lt}/q_{l,t-1}$ and $i_{lt}/i_{l,t-1}$ of the equations shown in this chapter. The resulting TFP Fisher annual changes are linked to the base year 2010 (chain-linking) to obtain the time series presented in this brief.

As the volatility of crop yields could have an impact on agricultural output, a three-year moving average is applied to reduce the weather effect.

The main statistical source used in this brief is Eurostat Economic Accounts for Agriculture, but other statistical sources are used especially to correct the input weights and reflect imputed costs. More specifically, the sources are:

- Volume changes of agricultural outputs and inputs (except labour and land): aact_eaa05, volume Indices, n-1 = 100, production value at basic prices. Volume indices are derived from values at constant prices (aact_eaa03) as the changes in values are imputable to volume changes when prices are fixed.
- Value weights of agricultural output and inputs: aact_eaa04, chain linked volumes (2010), production value at basic prices.
- Volume index for labour input: aact_ali01, Change in Total labour input measured in 1000 AWU. This dataset also allows for a correction of the weight for labour costs to cover the family labour costs: the compensation of employees is divided by the share of paid labour over total also directly available from the same source.
- Volume index of land use: apro_cpsh1, change in Total UAA (main area).

Complementary data is taken from: Eurostat Farm Structure Survey (ef_mptenure) to assess the share of rented land (to correct the weight of land input by including the owned land) as well as additional data to correct the weights for capital productivity to account for opportunity cost of capital: data: Government bond yields, 10 years' maturity (irt_lt_gby10_a) and data from the Farm Sustainability Data Network to estimate the national average depreciation rate of fixed assets.

[23] Intermediate inputs include energy and lubricants, fertilisers, feed, seeds, veterinary expenses, maintenance and other goods and services used for production.

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