EU Agricultural Markets *Briefs*

No 10 | December 2016

Productivity in EU agriculture
- slowly but steadily growing

Contents

Agricultural productivity has gained renewed interest. Productivity growth has enabled food to become less scarce (and hence cheaper) in the 20th Century. One question is whether it can do so again in the 21st Century, as this is seen as one prerequisite to meet the challenge of feeding more than 9 billion people by 2050, by achieving more with less. Agriculture and the environment within which it operates can differ substantially between Member States. Thus the question about how productive agriculture is and how to breach the gap between those lagging behind and the frontrunners remains pertinent.

In this *Brief*, we analyse how productivity, as measured by Total Factor Productivity (TFP) growth, evolved in the EU-28 and in the Member States, and identify the different drivers associated with it.

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Agriculture and Rural Development

1. Introduction

For a number of reasons, agricultural productivity increase has gained renewed interest. Productivity growth has enabled food to become less scarce (and hence cheaper) in the 20th Century. The question is whether it can do so again in the 21st Century. The pressure on our agricultural resource base has increased, due to growing food and industrial demand driven by demographic and disposable income changes. On the supply side there is growing competition from outside agriculture for the same production factors (land, labour, capital).

The European Commission has launched an ambitious program towards a resource efficient Europe in 2020. As a consequence, the agricultural sector is challenged to achieve more with less. While there is a general belief in the progress of technology to improve resource efficiency, this is challenging in agriculture, as working with living organisms in outside conditions introduces variability and limits to growth.

To monitor progress made towards higher productivity, which indicates an improved output over input ratio, Total Factor Productivity (TFP) offers an interesting starting point. After introducing the TFP-index and its potential use, this brief investigates the TFP-scores for the EU as a whole and its different Member States from 1995 onwards and tries to explain some of the main trends. The brief ends with some key lessons from Member States or periods with growing or declining TFP measurement.

2. Why monitoring productivity growth?

While in the past main gains is agricultural output were achieved by increasing resource intensity (more land, capital and intermediary inputs brought into production), the last decades productivity increase has led production growth, allowing for the saving of resources while output grew further. The increase in agricultural productivity allowed for a sustained decrease in real agricultural prices, and hence food prices, contributing to a decreasing share of food in the overall consumer expenses.

Productivity growth is of interest as it is often argued that our world is shifting from demand constrained to supply constrained. One of the reasons mentioned for the recent food price spikes was the inability of supply to keep up with demand growth. Demand is growing due to population increase, increases in GDP and hence disposable income and the gradual shift towards the Western, more protein rich diet. FAO projects a necessary 60% increase in food production by 2050 to feed our growing and more demanding population. At the supply side, further area growth is constraint by competition from other users (afforestation, urbanisation, leisure, infrastructure etc.), while also pollution and erosion are putting a brake on the available land. Likewise, other agricultural inputs experience increasing competition, become more scarce and are subject to environmental and climate constraints.

Therefore, the majority of the required increase should be reached by productivity growth. At the same time, environmental sustainability concerns, climate change (and the possible contribution of agriculture to its mitigation), as well as competition with other economic activities for scarce resources, are expected to limit the potential to further accelerate productivity growth. There are already first signs of productivity growth slowing down in some highly productive regions.

Monitoring productivity growth is of interest as it is seen as the main answer to cope with the challenge of feeding the world sustainably, but it is at the same time affected by the challenges posed by it.

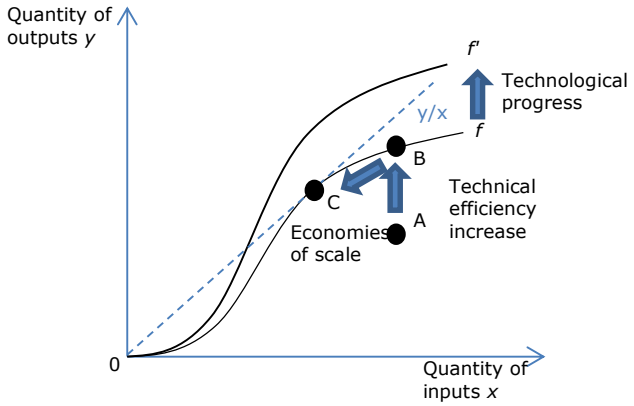
3. What is TFP?

TFP is the main indicator to measure changes in productivity, as it is considered more encompassing than partial productivity indicators such as labour or land productivity. TFP[1] growth can be defined as the *ratio between the change in production volumes over a considered period and the corresponding change in inputs (or factors) used to produce them* and hence measures the growth in productivity over a given time span. An increase in TFP reflects a gain in output quantity which is not originating from an increase in input use. TFP reveals the joint effects of many factors including new technologies, efficiency gains, economies of scale, managerial skill, and changes in the organization of production. Graph 1 shows possible pathways to improve productivity. One way is to shift the production frontier upwards by implementing new technologies (moving from f to f'). Another way is to increase the technical efficiency by better applying existing technologies (catching-up

[1] OECD refers to MultiFactor Productivity (MFP) acknowledging that not all input factors (nor all type of outputs) are accounted for in the calculation

through better management, going from A to B). Economies of scale refer to optimizing the scale of operations to achieve a better output over input ratio (from B to C).

Graph 1 Pathways for productivity growth



Source: Latruffe (2010)

There is much debate in the scientific community on how to measure productivity and efficiency, as this poses major challenges both from a methodological and data availability perspective. Main distinction can be drawn between the index methods based on agricultural economic accounts and the frontier-based methods which explicitly take the applied production technologies into account. As this brief attempts a first exploration of TFP-measurement for the EU and its Member States, the index methods are best suited, given their relatively straightforward calculation procedure and the absence of assumptions on applied technologies, which could differ substantially between regions and sectors, as well as over time.

This *Brief* makes use of the Fisher-index of TFP, which combines both the Laspeyres' and the Paasche Indices. As both output and inputs are expressed in term of volume indices, the indicator measures TFP growth. The change in production and input volumes is measured over a defined period (2005=100). To aggregate the different output (and input) volume indices, the production (and input) values are used as weights. This allows capturing the relative importance between output or input. More information on the calculation of TFP and data necessity can be found in annex 1.

TFP is one of the three impact indicators[2] for the general CAP objective of promoting a viable food production. Impact indicators measure the outcome of an intervention beyond the immediate effects. It is also used to evaluate the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-Agri[3]).

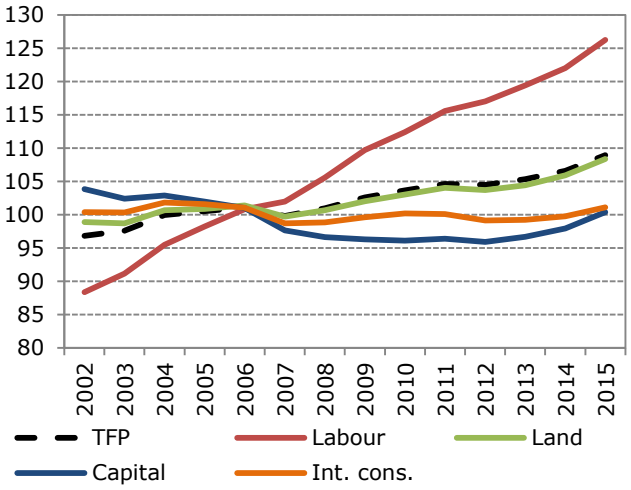
4. TFP growth in the EU…

Productivity in the EU has increased over time, albeit at a slower rate in recent years then in the past. While the growth rate surpassed 1% per year between 1995 and 2005, it slowed down to around 0.8% between 2005 and 2015. TFP grew with 9% in 2015 compared to 2005 (Graph 2). In 2014 and 2015 TFP growth accelerated, given the favourable crop conditions boosting crop and animal production.

… mainly driven by labour reduction

When comparing TFP growth to partial productivity indicators over the longer run, it becomes clear that labour productivity growth has contributed most to productivity gains.

Graph 2 TFP and partial productivity growth in the EU-28 (3-year moving average, MA[4])



Output growth has been achieved in a context of a shrinking workforce. Since 2005 the volume of agricultural output has increased by about 6%, but this number is quite volatile given the economic, agronomic and climatic uncertainties characterizing agriculture. Between 2005 and 2015 the total workforce in agriculture declined with about 25% to around 9,6 million full time equivalents, in line with

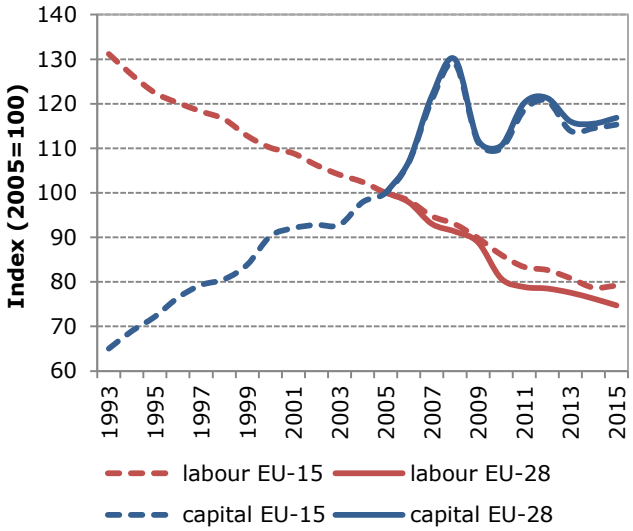
[2] Commission Implementing Regulation (EU) No 834/2014 of 22 July 2014 laying down rules for the application of the common monitoring and evaluation framework of the common agricultural policy, OJ L 230, 1.8.2014, p. 1-7.

[3] https://ec.europa.eu/eip/agriculture/en/content/EIPAGRIabout

the restructuring in the direction of fewer, but larger farms (Graph 3).

Labour has to a large extend been substituted by capital. With capital investments increasing, productivity per unit of capital decreased (Graph 1Graph 2). Capital productivity shows an overall decreasing trend prior to the financial crisis, indicating that investments in machinery, buildings and alike have played a major role in the realization of output growth and the substitution of labour. This is also visible from the development of capital[5], which increased at an average growth rate of 4% per year prior to the crisis to fall back afterwards (Graph 3). As a consequence, after the financial crisis capital productivity growth is recovering, mainly linked to this slowdown in investment growth.

Graph 3 **Evolution of labour force and capital formation in the EU**



Source: DG AGRI based on EAA

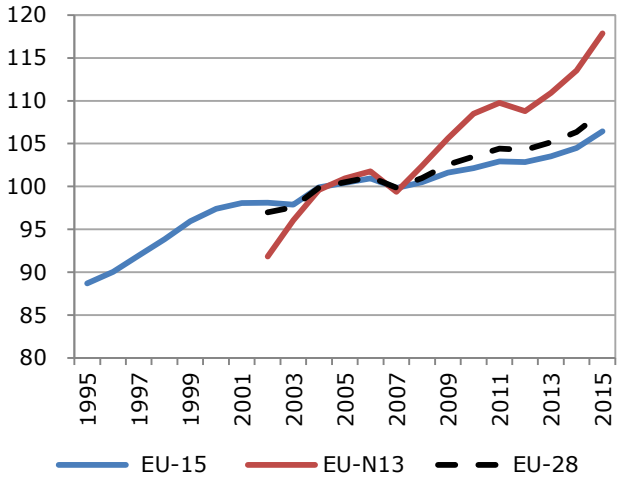
The growth in intermediate inputs use has remained largely in line with overall output growth, with the exception of bad harvest year 2012, while land productivity growth also improved, as outputs grew while utilised agricultural area declined by around 5%.

… and by the EU-N13

Both in the EU-15 and the EU-N13 TFP growth has increased compared to 2005 (Graph 4). Over a longer time horizon, important differences are however noticeable. Member States which joined the EU after 2004 have given an impetus to overall EU TFP growth.

These countries are still undergoing a stronger transition and restructuring compared to the EU-15 Member States. Increased investments in farm technology, logistics, R&D, accompanying services and infrastructure all contributed to this strong growth rate. The access to EU CAP subsidies undoubtedly helped. Right after accession and prior to the crisis, TFP growth contracted, especially in the EU-N13, due to a major crop failure mainly in Romania, Bulgaria and Hungary. Their overall output volume dropped considerably in 2007 to recover again in 2008.

Graph 4 ***TFP-index grows faster in the EU-N13 compared to EU-15 (2005=100)***



When analysing the TFP annual growth rates prior and post 2005 (Table 1), it is remarkable that the high growth rate in the EU-N13 is in fact offset by the lower growth rate in EU-15. Although EU-N13 growth rates are relatively high (over 1.6%/y), the share of EU-N13 in overall EU agricultural output is still limited. EU TFP growth therefore remains mainly driven by developments in the EU-15. Especially between 1995 and 2000 EU-15 experienced important gains in productivity, after which a period of cooling down started. In terms of productivity growth catching-up takes place between newer and older Member States.

Table 1 TFP annual growth

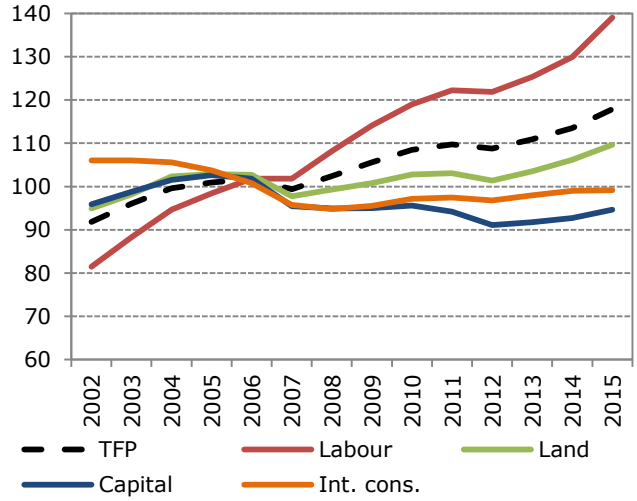
	1995-2005	2005-2015
EU-15	+1.3%	+0.6%
EU-N13		+1.6%
EU-28		+0.8%

Higher labour productivity growth is the main reason for TFP increase in the EU-N13, at the expense of

[4] To smoothen out the effect of weather variability, the 3-year moving average TFP is taken. See Annex 2 also for more explanation.
[5] Gross Fixed Capital Formation

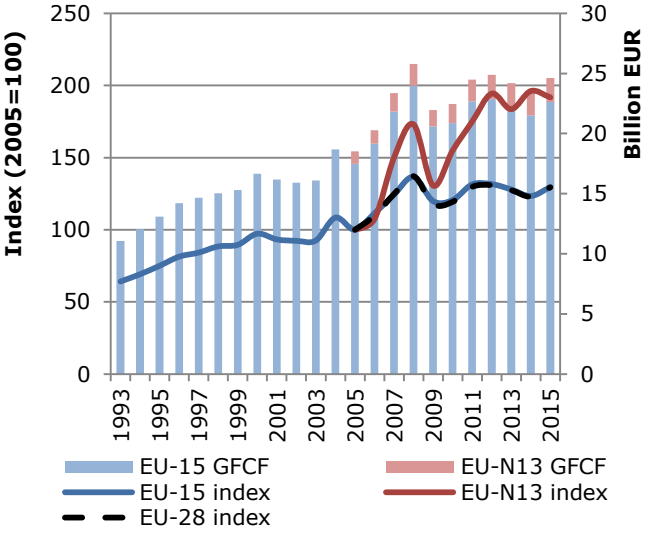
capital productivity growth, which evolved negatively (Graph 5).

Graph 5 Evolution of total and partial factor productivity in the EU-N13 (3-year MA)



During the ongoing restructuring in the direction of more technology intensive and larger farms, labour is substituted by capital. Between 2005 and 2015, the total labour force reduced by 33%, while total capital use (in volume terms) increased by 10%. Total output only increased by 5%, explaining the downward path of capital productivity.

Graph 6 Evolution of machinery capital formation in the EU-13 compared to EU-15



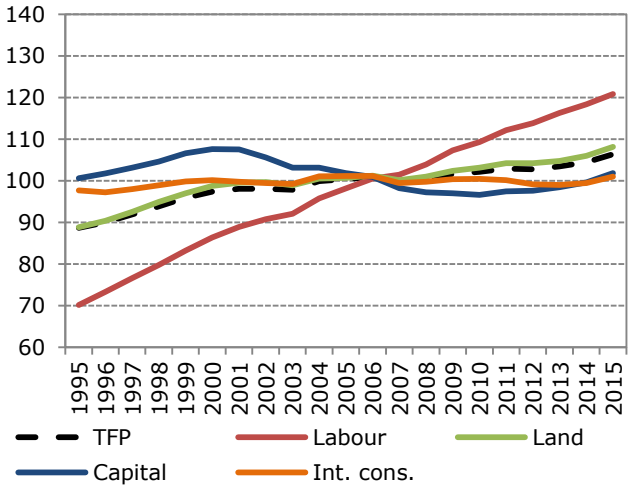
During the ongoing restructuring in the direction of more technology intensive and larger farms, labour is substituted by capital. Between 2005 and 2015, the total labour force reduced by 33%, while total capital use (in volume terms) increased by 10%. Total output only increased by 5%, explaining the downward path of capital productivity.

Graph 6 shows a further strong increase in machinery investment in the EU-N13 after the drop due to the financial crisis as compared to stabilization in the EU-15. Investments in absolute terms however remain small compared to the EU-15. With output growth volatile and close to zero, main gains in the EU-N13 are achieved by input contraction and substitution.

In 2012 TFP growth was slightly negative, as opposed to the strong growth in the previous periods. This is due to the combined effect of a drop in output of nearly 8% compared to the previous year (due to drought) and a temporary stop in labour force decline. While labour productivity growth was still slightly positive, its relative decrease was strongest compared to the other factors. Afterwards, TFP resumed its growth path as did the labour outflow. Interestingly, there is a strong correlation between the growth in intermediate input and output volume[6], indicating the importance of input use for output growth in the EU-N13.

Compared to EU-N13, the TFP growth in the EU-15 is lower in the last 10 years (Graph 7).

Graph 7 Evolution of total and partial factor productivity in the EU-15 (3-year MA)



Total output grew with about 16% between 1995 and 2015. TFP growth is also driven by labour productivity gains due to the continued outflow of workforce. Total workforce reduced with a steady pace from 7.2 million in 1995 to 4.9 million in 2015, or an annual reduction of 1.5%. Total capital consumption showed a more volatile path. In the early nineties production grew faster than capital consumption, with slight gains in capital productivity as a consequence, to reverse

again in the years 2000 until the economic crisis, after which capital inflow decreased while output grew further, improving capital productivity once more.

The joint realization of output increase, input contraction and input substitution offer first indications of a movement along the production frontier towards a new mix of inputs, while the higher growth numbers of the EU-N13 also hint towards more efficiency gains (and hence a movement towards the production frontier of the EU-15).

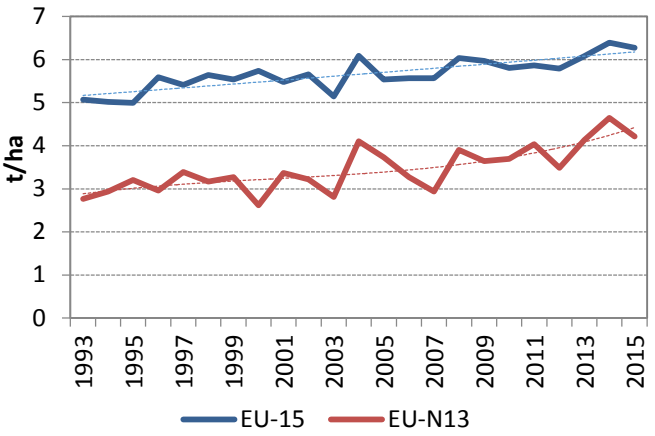
5. Comparing growth and level

Our current TFP methodology does not allow assessing differences in productivity level between the different Member States, for that a frontier approach is better suited[7]. The strong growth numbers in the EU-N13 can be explained by efficiency gains due to a larger distance from the technology frontier. The closer to the frontier the more difficult it is to further improve. A combined effect of structural change, financial aid through the CAP, investments and the adoption of technologies with proven effect from the frontrunners, explains the catching-up taking place.

Partial indicators help to show the difference in productivity level.

In the EU-15, cereal yields steadily increased from 5 t/ha in 1993 to over 6 t/ha in 2015, with outliers such as Belgium reaching 9.6 t/ha. The EU-N13 still lags behind and reaches only a little over 4 t/ha, although also here the gap is closing, especially after 2005 (Graph 8). EU-N13 frontrunners Latvia and Estonia show yield growth of more than 4% per year between 2005 and 2015.

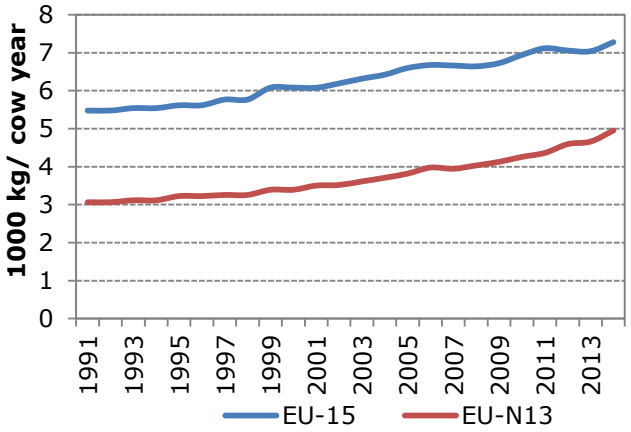
Graph 8 Cereal yield



On average, the EU-N13 also lags behind with respect to milk yield (Graph 9), with a difference of 2 tonnes per dairy cow per year, but annual growth outperforms the EU-15 (1.7% compared to 1.1% between 2005 and 2014). Estonia and Czech Republic combine high yields (over 7700 kg/cow) with high annual growth rates (4% and 2.6%), while also Latvia and Lithuania have high yield growth (3%/y) starting from a lower base.

Pig carcass weight, another partial productivity indicator, shows decreasing absolute differences and a different growth path between the EU-N13 and the EU-15, with growth slowing down in the EU-15 while it is accelerating in the EU-N13 after a period of stabilization.

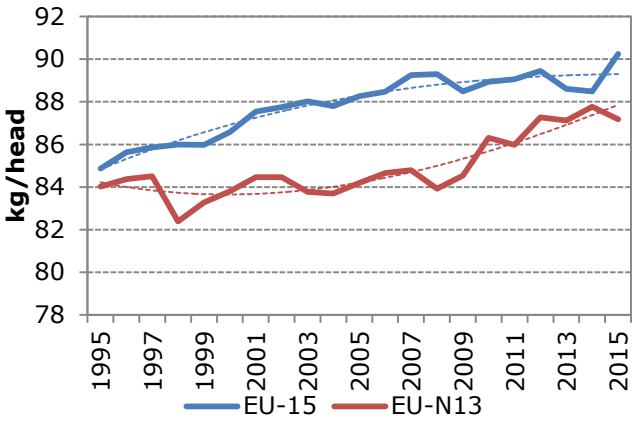
Graph 9 Milk yield from dairy cows



Graph 10 Pig carcass weight

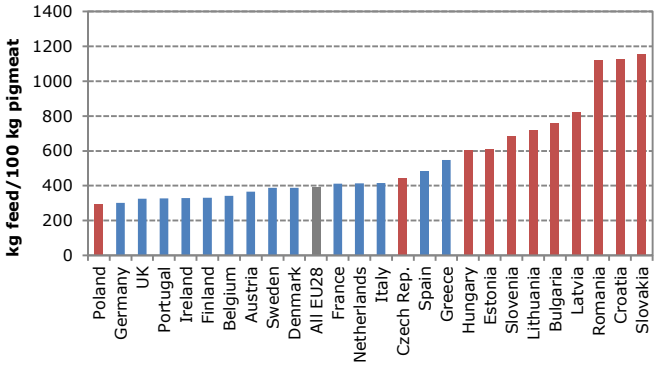
[6] Intermediate input and output volume follow a similar volatile growth path, while the other factors are more on trend

[7] This comes with caveats as well



The Feed Conversion Ratio (Graph 11) also confirms the gap still existing between the new and old Member States, with the new spending considerably more feed per kg of pigmeat compared to the old, except for Poland, an important pig producing country. Not entering into the debate of feed composition, Romania, Croatia and Slovakia even spent 3 times the EU-28 average, so important efficiency gains can still be made.

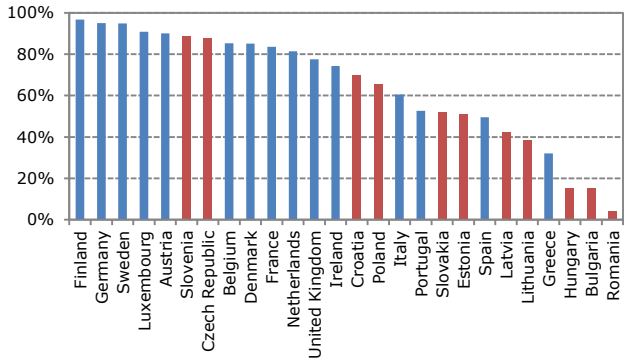
Graph 11 Pig feed conversion ratio in 2015/16



Also with respect to inputs and mechanisation differences are still huge, the latter already demonstrated in During the ongoing restructuring in the direction of more technology intensive and larger farms, labour is substituted by capital. Between 2005 and 2015, the total labour force reduced by 33%, while total capital use (in volume terms) increased by 10%. Total output only increased by 5%, explaining the downward path of capital productivity.

Graph 6. While in the EU-15 (especially in the North) on average more than 80% of the farms possess a tractor, this is far from the case in the EU-N13, with Hungary, Bulgaria and especially Romania lagging considerably behind (Graph 12).

Graph 12 Share of holdings with a tractor in 2013



Source: FSS

A thorough analysis of TFP within the FP7 research project Compete[8], based on FADN data and following a metafrontier approach[9] considering cereal, milk and pork production in 24 EU member countries, allows comparing TFP levels between Member States and regions. In line with the above, the metafrontier analysis showed that despite a period of almost 10 years after accession the productivity differences in the agricultural sector among as well as within countries are substantial[10]. For cereals the lowest TFP level indexes were estimated for regions in the United Kingdom, south France, east Germany, the north Czech Republic, west Austria, central and east Slovakia, Latvia and most of regions in Bulgaria and Romania. The most productive regions can be especially found in Spain, Italy, Germany and Denmark. For milk, the lowest TFP level indexes were estimated for regions situated especially in new Member States (Latvia, Slovakia, Romania and Bulgaria). The most productive regions can be found in Spain, Italy, the Netherlands and Denmark. For pork, most productive regions can be found in Denmark.

6. Factors explaining TFP-growth

But what does actually stimulate productivity growth. As explained in the introduction, productivity improvements can be realized through application of better technologies and/or more efficient

[8] Cechura, L. et al. (2014). Total Factor Productivity in European Agricultural Production. Compete working paper N9.
[9] meaning that one frontier production technology is estimated for all farms across the EU
[10] Unlike us, the authors did not observe catching up taking place between the regions. Note that the followed approach and dataset (FADN farms versus EAA) differ considerably

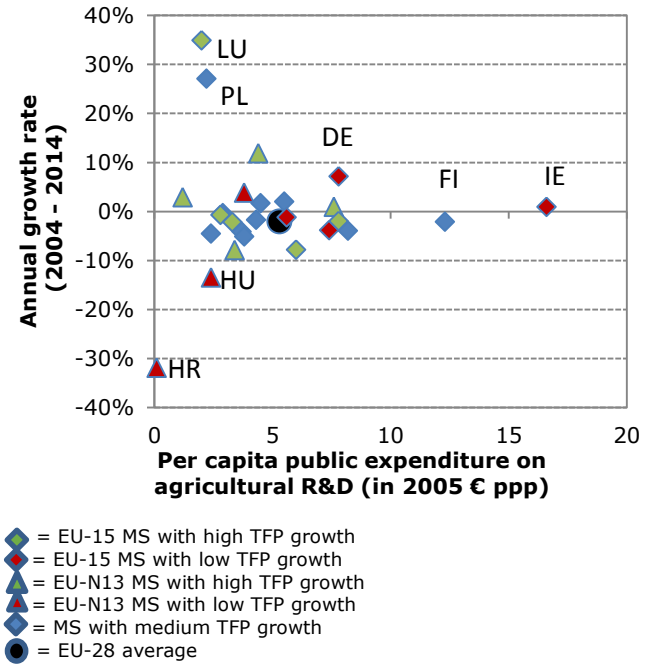
management, either technical, allocative or scale[11]. Some of the factors are at the discretion of the farm manager and depend on his/her management skills, such as some efficiency improvements, while others go beyond the individual farm manager, such as the natural environment, the technology development, investment in R&D, the advisory system and infrastructure, availability of similar farms and value chains, applied policy framework etc. While an in-depth analysis of the degree to which these factors explain changes in TFP is beyond the scope of this Brief, we do provide some basic insights below.

Investments in R&D and knowledge sharing

The most important factor determining productivity growth in the long run is innovation, which, in turn, is driven by research investment. Most studies find a significant positive effect on productivity of investments in innovative technologies. New technologies such as Big Data, either open source or not, Plant breeding technologies, Multi-Actor business models, precision farming and alike could shift the technology frontier upwards. In a frontier-based analysis, the adoption of new technologies can be verified quite straightforward by an upward shift of the entire production frontier (see Graph 1). For accounting-based TFP-growth measures such as the Fisher-index applied here, this is not straightforward. In the FP7 project Compete the analysis revealed technical change as the most important factor contributing to TFP development (compared to efficiency change). The technological change apparently results in labour and land savings and capital and material increases. The technological change where labour is substituted by capital correspond to general expectations and is also confirmed when we analyse Member States' partial productivities.

One proxy[12] for the technology development in agriculture could be the Total intramural R&D expenditure on agricultural sciences[13]. Fuglie and Heisey (2007) estimate the mean rates of return to public investments in agricultural research ranging from 20 to 60 percent, depending on the methodology and data used. As shown in Graph 13, on average in the EU-28 the public expenditure on R&D in agriculture is stabilizing.

Graph 13 Per capita public expenditure on R&D in agriculture in 2014



Source: DG AGRI based on Eurostat gba_nabsfin07

From the graph, there is no obvious link between the per capita public expenditure on R&D in agriculture and a high or low TFP growth. Also the link with the growth of this expenditure over time and TFP growth is not straightforward. More advanced analysis is required to show this. There is always a time lag between technology development and adoption, while other factors are at play as well, such as extension services, available financial instruments, institutional setting etc. According to Yu et al. (2015)[14], the knowledge stock of R&D in agriculture[15] is considered to be a better indicator of technological progress than R&D investment. This is because there are often long lags before farmers begin accessing the outputs of R&D investment.

To speed up the uptake of innovation, the European Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI) was launched by the European Commission in 2012. It aims at fostering a competitive and sustainable agriculture and forestry sector that "achieves more from less". To achieve this

[11] Technical efficiency improvement refers to a movement towards the technology frontier by reducing inputs at constant output or expanding outputs while maintaining inputs constant or even decreasing them. Allocative efficiency refers to changing the input and/or output mix to optimize cost/benefits. Scale efficiency refers to changing the scale of the enterprise to the point of optimal returns to scale

[12] Another proxy is the share of innovative firms in agriculture (inn_cis7_type), data are however scarce

[13] Eurostat variable rd_e_gerdsc

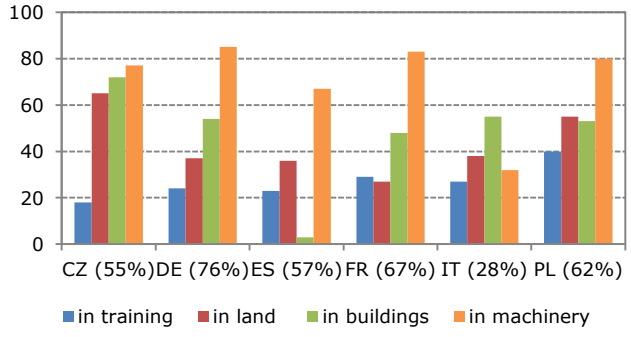
[14] Yu Sheng et al. (2015). Comparing Agricultural Total Factor Productivity between Australia, Canada and the United States, 1961-2006. International Productivity Monitor (29).

[15] Obtaining consistent data series per Member State for this proxy is even more cumbersome due to data lacks

aim, the EIP-AGRI brings together innovation actors (farmers, advisors, researchers, businesses, NGOs, etc) and helps to build bridges between research and practice. Via a dedicated working group on Agricultural Knowledge and Innovation Systems (AKIS), the Standing Committee for Agricultural Research (SCAR) assists the EIP through the development of innovative Horizon 2020 instruments.

A recent JRC-study[16] investigated investment behaviour of farmers in 6 EU countries[17]. The study revealed that 56% of the farmers surveyed intend to invest in the period 2014-2020. Overall, 40% of the farms planned to invest in machinery and equipment, while investment intentions in land, buildings, training, and quotas and production rights are less frequent (see Graph 14 also). Increase in production quantity is however not often cited as main benefit[18]. Many of them admit to applying for investment support. Amongst the surveyed countries, they found that Italian farmers stated they were less likely to intend to invest than others in 2014-2020 (28%), while French and German farmers are the most likely to invest (67% and 76%, respectively). Largest farms (i.e. those above 50 hectares or 50 livestock units (LSU) for livestock and mixed farms) have a greater intention to invest. They also observed differences in the intentions to invest by specialisation, mostly for arable crops. Farm investment strategies are also path dependent: farmers intending to invest are largely the same as those who invested recently.

Graph 14 % of farmers intending to invest in each asset type in proportion of the farmers intending to invest in 2014-2020*



* The number between brackets indicates the percentage of farmers intending to invest

[16] Lefebre et al. (2014). European farmers' intentions to invest in 2014-2020: survey results. JRC-report.
[17] Czech Republic, Germany, Spain, France, Italy and Poland
[18] Improving of working conditions is

Managerial skills

In order for new technologies to be picked up by farmers and applied to their intended use, farmers' management skills are important. Good management practices also help to improve the technical efficiency, i.e. to produce more with the same set of inputs. While not self-evidently measurable, proxies such as age, education/training and full-time farm employment are often indicative. The effect of age is dual as elderly farmers are more experienced but at the same time more reluctant to change. The age distribution of farmers is similar in the EU-15 and the EU-N13, with about 30% of farms having a manager older than 65 (FSS, 2013), while a little over 5% of the farms have a farm manager younger than 35. If we however consider the farm size by age, farmers less than 35 have significantly larger farms (30 ha on average versus 7 for the 65+ and 16 on average). Of the Member States with high TFP growth, only Austria has more young managers compared to the 65+. In Denmark, Ireland and the UK, MS with low TFP growth, we see the share of young farmers declining over time.

Education and training is another proxy for new technology uptake and better farm management. As indicated in Graph 14, between 20 to 40% of the farmers intending to invest, consider investments in training. 70%[19] of all farm managers did not receive any training, while only 8% has had a full agricultural training. This increases to 20% for the farm managers under 35 years old. Member States[20] with high TFP growth tend to have more managers with full agricultural training. Luxemburg, also with high TFP growth, performs best with 50% of managers having followed a full agricultural training. Romania is the exception, with more than 96% of farm managers only having practical experience.

Managers of small farms tend to put in less working time than those of bigger farms. One out of five farmers with less than 5 ha of agricultural land spends less than a quarter of his or her working time on the farm. This number declines with increasing farm size: 82% of farmers with 100 ha or more work full time. With the drive toward larger farms and more specialisation, full time employment is also increasing (even in absolute terms for the largest farms in the majority of MS). This leads to economies of scale.

[19] CAP context indicator C24 Agricultural training of farm managers
[20] Poland, Latvia, Czech Republic, Austria, Belgium

Policies

Whether policy reform enables or disables productivity growth depends on the policy objectives pursued and the policy instruments chosen. While increased market orientation for example can be associated with a drive towards more efficiency, increased regulation might generate the opposite effect.

Rizov et al. (2013)[21] investigated the impact of subsidies from the Common Agricultural Policy on the total factor productivity of farms in the EU. As they explain, there are various channels through which subsidies impact on (aggregate) productivity. They may either increase or decrease productivity and thus the net effect may be either positive or negative. The negative impact of subsidies on productivity may result from allocative (and technical) efficiency losses owing to distortions in the production structure and factor use, some budget constraints and the shift of subsidies to less productive enterprises. The positive impact may stem from investment-induced productivity gains caused by the interaction of credit and risk attitudes with subsidies (subsidy-induced credit access, a lower cost of borrowing, a reduction in risk aversion and an increase in productive investment). The authors empirically study the effects of subsidies on productivity using samples from the Farm Accountancy Data Network for EU-15 countries. Their main findings are clear: subsidies had a negative impact on farm productivity in the period before the decoupling reform was implemented; after decoupling the effect of subsidies on productivity was more nuanced, as in several countries it turned positive. Main reason is that the negative effect of subsidies (allocative efficiency loss) is likely negatively and the positive effect (investment-induced productivity gain) is likely positively correlated with decoupling; thus one can expect that coupled subsidies will have a smaller positive or a larger negative impact on productivity relative to decoupled subsidies.

Mary (2013)[22] investigated the effect of Pillar 1 and Pillar 2 CAP subsidies on French crop farms using a panel data approach. The results show that set-aside, LFA payments and livestock payments have a significantly negative effect on productivity. Minviel and Latruffe (2014)[23] analysed in a meta-analysis 195 results about effect of subsidies, extracted from a set of 68 studies carried out from 1972 to 2014. The authors conclude that aggregating all subsidies received by farmers into total subsidies increases the probability of a negative effect of subsidies on farms' technical efficiency and, when isolated, investment subsidies are positively related to farms' technical efficiency.

Rural and supply chain development

An enabling environment is also essential to come to productivity gains. Investments in rural infrastructure, access to information (e.g. internet), presence of a well-developed supply chain and clusters of farmers all have spill-over effects on the farm. In the 2007-2013 Rural Development policy this was mainly realized through axis 1 (competitiveness of agriculture and forestry), axis 3 (quality of life in rural areas) and Leader (cross-cutting). Axis 1 received more than 40% of all EAFRD funding in Belgium, Hungary and Portugal (44%), Spain, Lithuania and in Poland (42%), countries with high TFP growth, whereas it accounted for less than 15% in Austria (13%), Finland, the United Kingdom (12%) and Ireland (10%), the latter 3 having relatively low TFP growth. The EAFRD contribution allocated to axis 3 was highest in Malta (33%), followed by Bulgaria (30%) and the Netherlands (30%). The allocation to this axis was at or below 10% in France (10%), Ireland and Luxembourg (8%)[24].

A well-functioning food chain has spill-over effects to the agricultural sector. Cechura et al. (2014)[25] performed a comparative analysis among different EU countries in four food processing industries to measure the productivity level of individual countries, sectors, and companies. High TFP was found in Germany, France, Italy, and the Netherlands in all sectors. TFP has a positive trend in the majority of EU member countries; only Bulgaria is an exception. The authors observed that some countries with average or low TFP levels in the processing industry are catching up but also countries with high productivity are improving their performance. Large differences in

[21] Rizov, M., et al. (2013). CAP subsidies and productivity of the EU farms. Journal of Agricultural Economics, 64(3), 537-557.
[22] Mary, S. (2013). Assessing the impacts of pillar 1 and 2 subsidies on TFP in French crop farms. JoAE, 64(1), 133-144.
[23] Minviel, J. J., & Latruffe, L. (2014). Meta-regression analysis of the impact of agricultural subsidies on farm technical efficiency. EAAE 2014 Congress 'Agri-Food & Rural Innovations for Healthier Societies'
[24] Note that measures implemented via Leader can contribute to all axes but mainly to axis 3 (for example in Ireland where axis 3 is implemented mainly via Leader).
[25] Cechura et al. (2014). Productivity and Efficiency of European Food Processing Industry. EU FP7 Compete project, Working paper N7.

productivity also exist between sectors and between companies within countries.

Structural change

EU agriculture is undergoing a continuous process of structural change, with decreasing numbers of farms which are increasing in size. Relative changes between sectors also take place. Farm numbers are continuously decreasing. Between 2005 and 2013, the average annual rate of decline stood at -3.7%, with greater losses in the countries that joined the EU in 2004 and 2007 (EU-N12: -4% per year) than in the older Member States (EU-15: -3.4% per year) . At the same time, between 2005 and 2013, the average standard output per farm increased by 5.7% per year in the EU-27. This growth rate was higher in the EU-N12 (+7.2% per year) than in the EU-15 (+5.1% per year).

A JRC-project on structural change shows the (relative) disappearance of mixed cropping and livestock farms in favour of more specialized farms and the drive towards larger farms. The first development improves technical and allocative efficiency, while the latter contributes to scale efficiency.

7. Member States with different growth

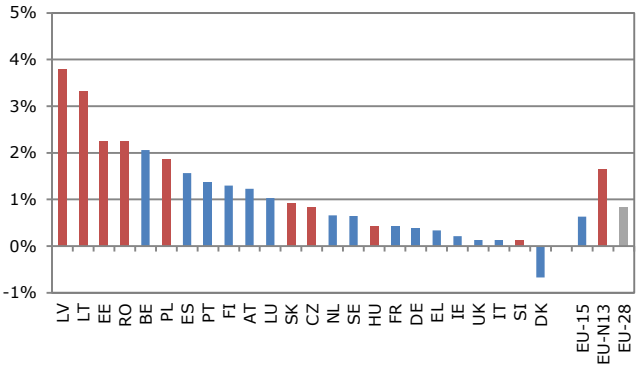
Having discussed some of the main trends in EU TFP development and the possible drivers which can explain these, we now turn our attention to the Member State level.

TFP growth on average

While the TFP growth path is of main interest, a first analysis of the average annual TFP growth for the different Member States across the period 2005-2015 already reveals important insights (Graph 15). Several Member States joining after 2004 are clearly ahead. Latvia, Lithuania, Estonia and Poland are best performing, with growth rates above 2% per annum, while also Romania reaches an average above 1%. Germany is the worst performing with a TFP which is on average contracting by 0.7% per year since 2005, mainly to be related to a decrease in (animal) output volume[26] while input volume remained largely stable.

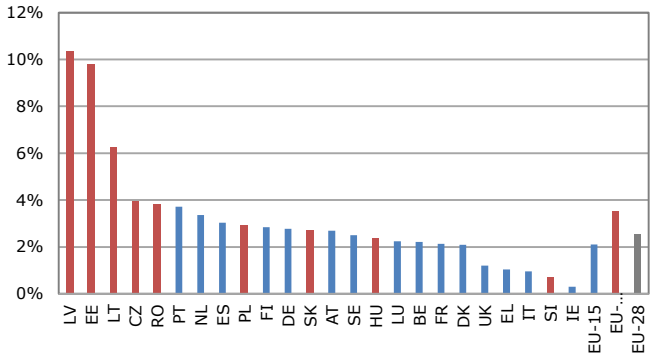
[26] As this is against expectations, a thorough data check shows inconsistencies between the index-evolution and actual reported production numbers. Also Intermediate input consumption indices demonstrate data issues.

Graph 15 Average annual TFP growth in EU Member States between 2005 and 2015[27]



As for the EU-N13 and the EU-15, TFP growth in the Member States is mainly driven by an improved labour productivity growth (Graph 16).

Graph 16 Average annual labour productivity growth in EU Member States between 2005 and 2015



In Latvia and Estonia, the average annual labour productivity growth reaches about 10%, which corresponds to a doubling of the labour productivity over the period 2005-2013. Also in Lithuania, Czech Republic and Romania labour productivity growth is high. Of all the Member States, none has negative labour productivity growth since 2005. In the UK, total labour force remained largely stable since 2006 and in Italy since 2009 while in Ireland it even increased after 2009, which can be related to the economic crisis. The low labour productivity in Slovenia mainly relates to a contraction in animal, and to a lesser extent crop output, while the total labour force also remained stable since 2009. The low TFP growth in some of the old EU Member States contradicts with their positive labour productivity growth, indicating negative productivity growths for the other factors.

[27] TFP 2015 = average(2013, 2014, 2015) and TFP 2005 = average(2003, 2004, 2005)
Average growth calculated as compound annual growth rate
Countries not depicted here due to data issues: Croatia (-2.2%/y; 2007=base), Bulgaria (+1.1%/y), Malta (-2.9%/y), Cyprus (+0.2%/y)

The compound annual growth rate however hides differences in pathways between Member States.

Different growth paths between Member States

… in the EU-15

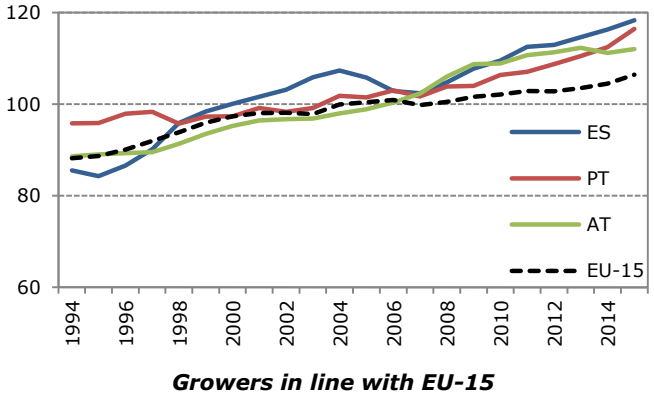
The TFP growth paths differ considerably across Member States both in magnitude and trajectory (Graph 17). Six Member States (Italy, France, Greece, Germany, Netherlands and Sweden) have a growth path which closely follows the EU-15 average, especially in more recent years. Another three (Spain, Portugal and Austria) are clearly ahead of the pack with strong and rather stable growth. Three Member States (Finland, Belgium and Luxemburg) show trend breaks over time. In Denmark, UK and Ireland, TFP is not growing at all compared to 2005.

What explains these differences and what can we learn from the fast growers? Spain and Portugal, two strong growers, followed a similar trajectory, with strong output growth (both in animal and crops) in combination with intermediate input growth, while especially labour contracted, combined with capital outflow especially in Portugal. In Austria, another strong grower, no capital outflow took place but land contraction instead, with a loss of about 500 thousand hectares (17%) of land, mainly permanent grassland.

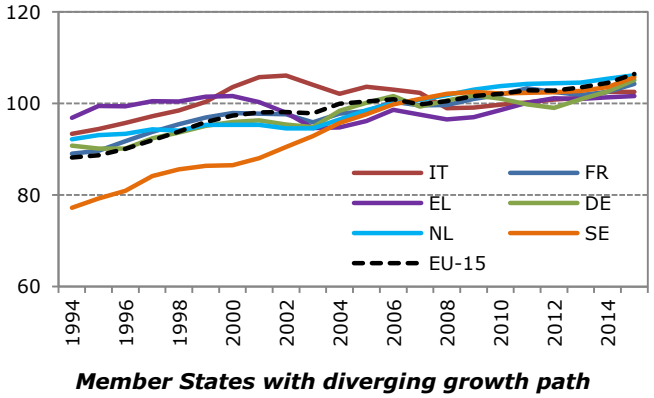
In Belgium, labour outflow and capital contraction contributed to growth, but this was until 2010 offset by increased intermediate input use (mainly feed for animal production). After 2010 feed, energy and fertilizer use decreased considerably. Output on the other hand picked up again (except for the bad crop harvest in 2012) explaining the TFP recovery. Luxemburg is a similar story. Finland lost ground due to several years of contracting crop output volumes bringing total output growth in line with total input growth.

Graph 17 TFP growth path for the EU-15 Member States

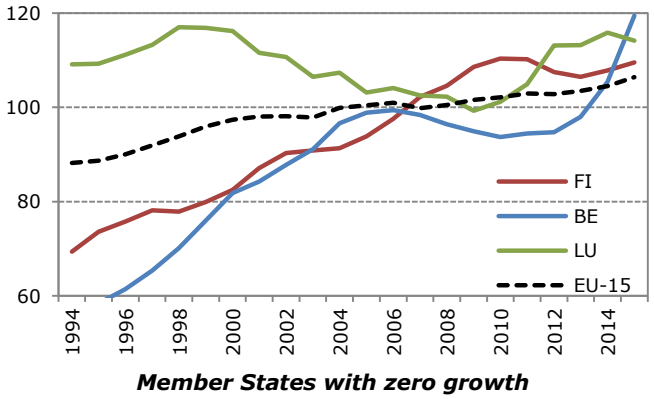
Strong growers



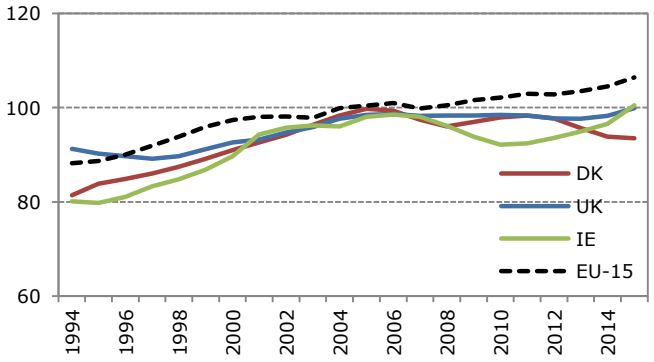
Growers in line with EU-15



Member States with diverging growth path



Member States with zero growth



On the other side of the spectrum we find the UK, Ireland and Denmark. In the UK, there is positive output growth, but this is matched by a similar total input growth, especially of intermediate inputs and capital, while the total labour force remained largely

stable, explaining the absence of TFP growth. In Denmark output growth is also realized with more intermediate inputs (mainly feed) (and not TFP). In 2013 output volume also contracted strongly especially in the animal sector[28].

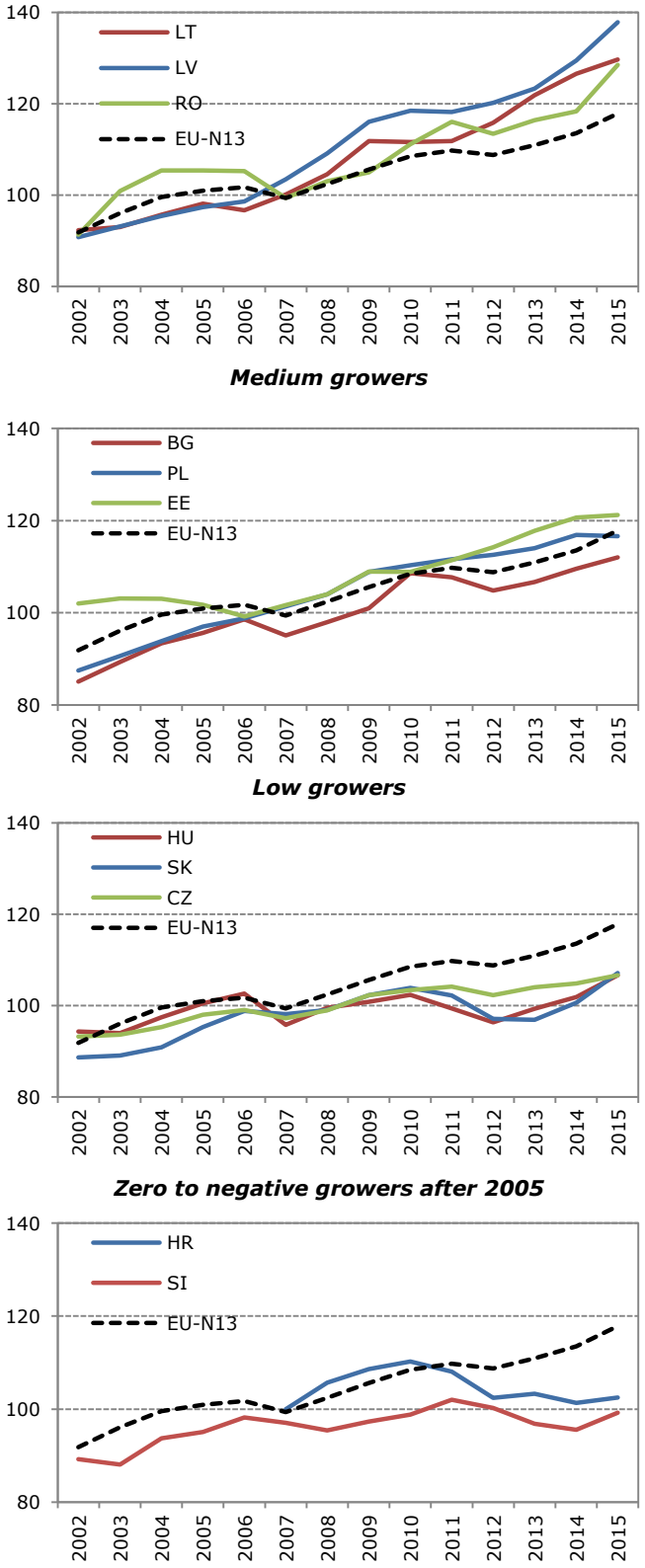
… and in the EU-N13

In the EU-N13 differences among Member States are larger compared to the EU-15. TFP-growth compared to 2005 ranges between -15% and +40%. The EU-N13 champions in TFP-growth are Latvia, Lithuania and Romania, mainly propelled by steady output increase combined with strong labour force reductions. Romania experienced a strong reduction in crop output volume in 2007, not compensated by the reduction in input factor use. It however quickly recovered in the subsequent years.

Estonia and Poland, both with a TFP growth around 20% compared to 2005, show a consistent increase since 2005. While Estonia's growth was temporarily stopped during the financial crisis, after which it picked up again, Poland's TFP grew with a slower pace after the crisis, as labour outflow reduced and crop and mainly animal outputs stagnated. Bulgaria demonstrated steep TFP growth up to 2010. Its main driver is strong labour outflow. At the same time, animal production volumes declined drastically, partly compensated by higher crop production. After a period of stagnation due to deteriorating capital productivity[29], its TFP growth picked up again in 2013.

In the third group with growth rates below 10%, encompassing Slovakia, Czech Republic and Hungary, the year 2009 was the turning point. In the case of Hungary and Czech Republic, a combination of continued capitalization and only moderate labour outflow in a context of stable outputs explains the stagnation. This is to a lesser extent also the case for Slovakia, where a lower animal output volume also contributed to the low TFP growth.

Graph 18 TFP growth path for EU-N13 Member States



Croatia and especially Slovenia are lagging behind. In Croatia total output volume contracted with 13% since 2007, as did total inputs. After 2010, especially crop output declined, explaining the drop. The labour

[28] Sheep and goat and other animal products (fur) in particular
[29] There was a strong decapitalization in 2009 after the crisis. Due to recapitalization in the next years, capital productivity decreased considerably

outflow is also limited. In Slovenia output volumes contracted while inputs remained largely stable.

A more in depth analysis could reveal which of the driving factors contributes most to explaining the differences between Member States. Some of the necessary data is however lacking.

Given the distance in productivity level (Chapter 5) with the EU-15, there is indication that efficiency gains (linked to improved management skills), adoption of technologies already used in the EU-15 (such as machinery) and structural change (farms and labour disappearing while farm size grows) are important explanations for the productivity gains.

8. TFP in the world

Coelli and Rao (2005)[30] examined the levels and trends in agricultural output and productivity in 93 developed and developing countries that account for a major portion of the world population and agricultural output. They make use of data drawn from the FAO and their study covers the period 1980–2000. Due to the non-availability of reliable input price data, the study uses data envelopment analysis (DEA) to derive Malmquist productivity indices. The study examines trends in agricultural productivity over the period.

Table 2 Weighted means of annual technical efficiency change, technical change and TFP change for the continents, 1980-2000 (Coelli and Rao, 2005)

Continent	Efficiency change	Technical change	TFP change
Africa	1.006	1.007	1.013
North America	1.000	1.027	1.027
South America	1.000	1.006	1.006
Asia	1.019	1.010	1.029
Europe	1.002	1.011	1.014
Australasia	1.000	1.018	1.018
Mean	1.009	1.012	1.021

Between 1980 and 2000, Asia realized the highest annual TFP growth of 2.9% (mainly due to efficiency growth of 1.9% per year) followed by North America (US and Canada), Australasia, Europe, Africa and South America. The latter reached the lowest growth rate of 0.6%, followed by Africa with 1.3% growth in TFP. Interesting is the predominance of efficiency change (or "catching-up") as a source for TFP growth in some continents, as opposed to others. Both in Asia and Africa efficiency change is the principal source of TFP growth, while in North America, Australasia and Europe technical change is the main driver.

A more recent study of Fuglie (2010)[31] presents a comprehensive global and regional picture of agricultural TFP growth between 1961 and 2007, also mainly based on FAO-data complemented with data from national sources to obtain input cost shares necessary for the weighting. The author used the Tornqvist-Theil growth accounting index of agricultural TFP growth. Fuglie does not find evidence for a general slow-down in agricultural productivity. The TFP growth he notices is mainly driven by rapid productivity gains in developing countries such as Brazil and China, as well as a more recent recovery of growth in countries from the former Soviet Union. Other developing countries (Sub Saharan Africa, West Asia, Carribean, Oceania) continue to rely on resource-led agricultural growth rather than productivity. The evidence in this study suggests TFP growth may in fact be slowing in developed countries while accelerating in developing countries, which is in marked contrast to the early findings of other studies which found developing countries to be falling further behind developed countries in agricultural land and labour productivity. The numbers projected in table 3 below also confirm our findings of decreasing growth in the EU-15 compared to the EU-N13.

Table 3 Agricultural TFP growth across regions (average annual %), Fuglie (2010)

	61-69	70-79	80-89	90-99	00-07	61-07
All developing countries	0.18	0.54	1.66	2.30	1.98	1.35
Transition countries	0.67	-0.26	0.25	0.73	1.92	0.61
All developed countries	1.21	1.52	1.47	2.13	0.86	1.48
Europe (except former SU)	1.17	1.31	1.22	1.63	0.59	1.21
Eastern Europe	1.23	-0.64	0.22	1.19	3.82	1.03

Box: TFP to measure agricultural sustainability[32]

Most existing metrics of agricultural productivity, including our approach, do not fully account for the use of environmental goods and services in agricultural production, thus provide only a limited means for assessing the long-term sustainability of agricultural productivity growth. Since TFP does not fully account for the use of natural and environmental resources in production, it needs to be

[30] Coelli, T. and Rao, D.S. (2005). Total factor productivity growth in agriculture: a Malmquist index analysis of 93 countries, 1980–2000. Agricultural Economics 32(S1), 115-134

[31] Fuglie, K. (2010). Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data. Chapter 4 in The Shifting Patterns of Agricultural Production and Productivity Worldwide. The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa.

[32] Based on: Fuglie et al. (2016). G20 MACS White Paper: Metrics of Sustainable Agricultural Productivity. Pp 68

supplemented with other measures in order to assess sustainability of agricultural production. One approach is to develop sets of agri-environmental indicators and track trends in these indicators alongside TFP. Another approach is to extend TFP to explicitly include environmental goods and services along with market-based goods and services, into a broader index of Total Resource Productivity (TRP). The advantage of such a TRP is that, by valuing environmental goods along with market goods, potential economic and welfare trade-offs between these outcomes are explicitly considered.

To date, comprehensive sets of agri-environmental indicators and TRP indices are not available. While there remains considerable uncertainty regarding how and what environmental goods and services should be included and how they should be valued, progress has been made in recent years in assembling preliminary sets of agri-environmental indicators and developing methodologies for measuring TRP. Nonetheless, agricultural TRP indices that may be developed over the next several years are likely to be selective in their inclusion of natural resource and environmental, due to both scientific and data constraints and limitations.

For a comprehensive assessment of sustainable agricultural productivity, there remain important gaps in fundamental scientific understanding of the relationship between agriculture and the environment. Without better scientific understanding, we cannot be confident that any proposed metric of sustainable agricultural intensification actually achieves its goals. Continued and enhanced support for fundamental research on sustainable agricultural systems will enable the development of improved productivity metrics at the appropriate scale.

In the future, use of new data tools, like remote sensing, and related bio-physical and ecological models may significantly reduce the cost of real-time and spatially-disaggregated assessment of the status of environmental resources used or affected by agriculture. This could contribute to construction of indices like TRP.

9. Some caveats

The findings of the current study need to be interpreted with caution as limitations exist in terms of data gathering and analysis. Due to the structure of the Economic Accounts of Agriculture it is not possible to distinguish at the input side between different sectors. This makes a comparison of TFP between different sectors extremely difficult. Reversion to other data sources (e.g. FADN) could allow for this kind of analysis.

With the growth accounting approach we also cannot easily draw a distinction between efficiency change and technological change as separate parts of the TFP change. The description of factors explaining TFP growth can also be underpinned more statistically. This would require an econometric analysis for which we currently lack consistent data.

Some further improvements in the representation of the input factors could be made. Due to lack of data, we currently do not distinguish between skilled and unskilled labour, land quality, while the calculation of service flows from capital stock could also be improved further.

The time series length differs between MS, making a long term comparison hard. For Croatia for example, 3-year averages are only available since 2007. The national data also suffer from data gaps and outliers, which necessitates the use of assumptions to complete the time series.

10. Conclusion

TFP allows for a comprehensive measure of productivity change over time. It measures the change in output that is not directly originating from a more intensive input use, but from changes in technology, efficiency, managerial skills and organisation of the production. It is an important impact indicator to monitor the reaching of the CAP-objective of a viable food production.

Productivity in the EU has increased over time, but at a slower rate more recently compared to the past. While the growth rate surpassed 1% per year between 1995 and 2005, it slowed down to around 0.8% between 2005 and 2015.

Our analysis reveals that TFP growth is stronger in the EU-N13, showing considerable growth over the last decade, while EU-15 members show moderate to negative TFP growth numbers. The TFP growth is mainly achieved by reducing the labour input intensity, which is more pronounced in the EU-N13. Given the distance in productivity level with the EU-15, there is indication that efficiency gains (linked to improved management skills), adoption of technologies already used in the EU-15 (such as machinery) and structural change (farms and labour disappearing while farm size grows) are important explanations for the productivity gains.

TFP growth paths differ considerably between Member States. Some are more hit by the financial and economic crisis as opposed to others. A further comparison of Member States with similar structures but other TFP growth paths might yield additional interesting lessons learnt.

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http://ec.europa.eu/agriculture/markets-and-prices/index_en.htm

Annex 1 – Methodology

Indicator Name	Total factor productivity in agriculture
Related general objective(s)	Viable food production
Definition	**Total factor productivity (TFP) compares total outputs relative to the total inputs used in production of the output. As both output and inputs are expressed in term of volume indices, the indicator measures TFP growth.** The change in production and input volumes is measured over a defined period (2005=100). To aggregate the different output (and input) volume indices, the production (and input) values are used as weights. This allows capturing the relative importance between outputs, or inputs. **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 input use.** As a result, TFP reveals the joint effects of many factors including new technologies, efficiency gains, economies of scale, managerial skill, and changes in the organization of production.
Unit of measurement	Index, 3 year-average
Methodology/ formula	TFP index is defined as the ratio between an **Output Index** (i.e. the change in production volumes over a considered period) and an **Input Index** (the corresponding change in inputs/factors used to produce them). 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 of the various products and the expenditure for each of the four considered production factors (intermediate inputs, land, labour, capital). Depending on the type of average applied and the chosen reference period for the weights, the TFP indicator assumes different analytical forms. **Laspeyres indices** are defined as arithmetic means with weighting factors referring to the time 0 (base year), while **Paasche indices** are harmonic means with weighting factors referring to the time t (current year). In formula, the TFP Laspeyres index is given by: $TFP_0^t\_L = \frac{O_0^t\_L}{I_0^t\_L} = \frac{\left(\frac{q_{1t}}{q_{10}} * w_{10} + \frac{q_{2t}}{q_{20}} * w_{20} + \ldots + \frac{q_{nt}}{q_{n0}} * w_{n0}\right) / \left(w_{10} + w_{20} + \ldots + w_{n0}\right)}{\left(\frac{i_{1t}}{i_{10}} * x_{10} + \frac{i_{2t}}{i_{20}} * x_{20} + \ldots + \frac{i_{rt}}{i_{r0}} * x_{r0}\right) / \left(x_{10} + x_{20} + \ldots + x_{r0}\right)}$, while TFP Paasche index is defined as: $TFP_0^t\_P = \frac{O_0^t\_P}{I_0^t\_P} = \frac{\left(\left(\frac{q_{10}}{q_{1t}} * w_{1t} + \frac{q_{20}}{q_{2t}} * w_{2t} + \ldots + \frac{q_{n0}}{q_{nt}} * w_{nt}\right) / \left(w_{1t} + w_{2t} + \ldots + w_{nt}\right)\right)^{-1}}{\left(\left(\frac{i_{10}}{i_{1t}} * x_{1t} + \frac{i_{20}}{i_{2t}} * x_{2t} + \ldots + \frac{i_{r0}}{i_{rt}} * x_{rt}\right) / \left(x_{1t} + x_{2t} + \ldots + x_{rt}\right)\right)^{-1}}$, where q_{jt} and i_{kt} are respectively the quantity of product *j* and factor *k* at time *t*, while w_{jt} and x_{kt} are the weights of product *j* and factor *k* within the agricultural sector. Finally, the geometrical average of the Laspeyres and the Paasche index gives the **Fischer index**, which benefits from the most suitable statistical properties. In formula, the TFP Fisher index is computed as follows:

	$TFP\_F = \sqrt{TFP\_L * TFP\_P}$
Data required for the individual operation	- volume indices and values of agricultural products at the most detailed level of disaggregation. All products of the holding are covered including the services and the non-separable secondary activities like transformation of agricultural products. In other terms the output of the whole agricultural 'industry' is accounted for. - volume indices and expenditure for land, labour and all intermediate consumption items at detailed level. For inputs without an explicit monetary value (i.e. own factors, such as family labour or owned land), an estimate should be calculated based on the cost of corresponding rented factors. For the own capital the volume index of gross capital consumption is used as a proxy. The opportunity cost of the own capital is estimated as the gross capital consumption divided by the national average depreciation rate (calculated based on FADN data) and multiplied by the 10-year interest rate on government bonds. Given the difficulty to estimate a depreciation rate by detailed items of the gross capital consumption, in this case only the aggregate is used. To summarise, capital cost is estimated as the gross capital consumption and the opportunity cost of own capital.
Data source	The **Economic Accounts for Agriculture (EAA)** from Eurostat. The volume indices calculated by Eurostat are Laspeyres indices and changes in volume are measured using the weightings for the preceding year to guarantee the weightings are relatively up-to-date (see Reg. N° 138/2004). They correspond to the term q_{lt}/q_{l0} of the equations displayed above. <u>Precise indicators chosen in the EAA</u>: - Change in output volume ($q_{lt}/q_{l0)}$: Volume Indices, n-1 = 100, Production value at producer price (aact_eaa05) - Output weights: Real price in Euro, 2005 = 100, Production value at producer price (aact_eaa04) - Change in input volume ($i_{lt}/i_{l0)}$ for every input except land and labour cost: Volume Indices, n-1 = 100, Production value at basic price (aact_eaa05) - Input weights: Real price in Euro, 2005 = 100, Production value at basic price (aact_eaa04) - Volume index for labour costs: Change in Total labour input measured in 1000 AWU (aact_ali01) - 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 also directly available from the EAA (aact_ali01) - Volume index for land costs: Change in Total UAA available in the EAA (apro_cpp_luse). - Complementary data is required from - the **Farm Structure Survey (FSS - Eurostat)** to assess the share of rented land (in order to correct the weight of land by including the own land) (ef_mptenure). - the **Agricultural Production Data – Crop Products** (**Eurostat**) for the volume index of the UAA (apro_cpp_luse). - - the **Farm Accountancy Data Network** to estimate the national average depreciation rate.
References/location of the data	Eurostat: EAA, APRO, ALI, FSS and FADN
Data collection level	Member States
Frequency	On request
Delay	Year N-2
Comments/caveats	The climatic conditions affecting crop yields have strong impact on the crop output and as a consequence on the indicator. Therefore a moving average over 3 years is to be calculated to smooth the weather effect. The level of detailed information required to compile the indices (especially for the Paasche Index) does not allow for calculating long time series and complicates the calculation for the EU aggregates. The length of the time series varies according to MS. There are breaks in time series and data is missing for some years, especially in the Agricultural Production Data. The methodology to value the fixed capital consumption seems to vary over time. Concerning the labour input any change in accounting rules has been normally smoothed. Nevertheless this volume index is to be checked very carefully because the TFP indicator is very sensitive to any variation in labour input.

Annex 2 – Weather effects and TFP

In our TFP-calculation we apply a 3-year moving average, in order to smoothen out adverse weather effects influencing the output volume and hence distorting the TFP measure. Yields in 2004 and 2014 for example were exceptionally high for the majority of crops, while those in 2003 and 2012 were exceptionally low. The high input prices in 2007 also impacted on yields. While the general tendency remains the same (see Graph 19), not using the 3-year moving average obscures the longer term trend in favour of yearly deviations.

Graph 19. Difference between TFP-estimates based on single year and 3 year average (EU-15: left axis; EU-N13 right axis)