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Please cite this paper as:

Bokusheva, R. and L. Čechura (2017-09-05), "Evaluating dynamics, sources and drivers of productivity growth at the farm level", *OECD Food, Agriculture and Fisheries Papers*, No. 106, OECD Publishing, Paris.
http://dx.doi.org/10.1787/5f2d0601-en

OECD Food, Agriculture and Fisheries Papers No. 106

# Evaluating dynamics, sources and drivers of productivity growth at the farm level

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OECD

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# EVALUATING DYNAMICS, SOURCES AND DRIVERS OF PRODUCTIVITY GROWTH AT THE FARM LEVEL

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This report measures and evaluates total factor productivity (TFP) of crop farms in the European Union (EU) in the period after the implementation of a series of important reforms of the EU Common Agricultural Policy (CAP). The analysis covers six EU Member states: the Czech Republic, France, Germany, Hungary, Poland and the United Kingdom. The data used in the analysis are based on the Farm Accountancy Data Network (FADN) data provided by the European Commission. To investigate sources of productivity growth, TFP is decomposed into three components – technical change, scale effect and technical efficiency. Technical change was found to be major source of productivity growth for most country samples for the two analysed periods. Technologies currently applied on crop farms were estimated to exhibit substantial economies of scale and therefore favour large-scale operations. However, economies of scale are not fully exploited which suggests the presence of some institutional constraints on farm growth. Large farms appear to be in a better position to exploit economies of scale; for West European countries covered in the report they were also found to exhibit larger persistent technical inefficiencies. Farm support payments were found to negatively influence crop farm productivity and efficiency of input use. More decoupled payments appear to be less distorting than other forms of support. A meta-level analysis of allocative efficiency shows that farms tend to be overcapitalised but to show relatively low allocative inefficiencies in their variable input use decisions. Substantial allocative inefficiencies appear also to exist in land and labour use. No significant economies of scope were found for the analysed crop production systems and levels of output aggregation. Farm flexibility was revealed to be determined mainly by the scale and convexity effects enabling cost efficient adjustments in the size of farm operations.

***JEL classification*:** D24, Q12, Q180

***Keywords***: Total Factor Productivity, farm flexibility, economies of scope, agriculture, European Union

### *Acknowledgements*

The authors are grateful to the Directorate-General for Agriculture and Rural Development of the European Commission (EC) for providing the data used in this study. They in particular appreciate information and technical support provided by Piotr Bajek and Francoise Huylebroeck, both from the EC. The authors also thank Selina Matthews and Lindsey Clothier from the UK Department for Environment, Food and Rural Affairs and József Fogarasi from AKI – the Hungarian Research Institute of Agricultural Economics – for their clarifications and helpful information on FADN data for England and Hungary, respectively. Technical support provided by Karine Souvanheuane, Martina Abderrahmane, Marina Giacalone and Frano Ilicic was highly appreciated. The report benefitted from comments and suggestions by Heinrich Hockmann, Laure Latruffe, Heiko Hansen, Koen Mondelaers, Frank van Tongeren, Catherine Moreddu, Hubertus Gay, Martin von Lampe, Shingo Kimura, Emily Gray and by the OECD Working Party on Agricultural Policies and Markets. The work was undertaken under the supervision of Frank van Tongeren.

This report was declassified by the OECD Working Party on Agricultural Policies and Markets in May 2017.

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## Executive summary

This report measures and evaluates total factor productivity (TFP) of crop farms in the European Union (EU) in the period after the implementation of a series of important reforms of the EU Common Agricultural Policy (CAP). To understand farm decisions and responses to policies and other changes the analysis uses data of individual farms. To investigate sources of productivity growth, TFP is decomposed into three components – technical change, scale effect and technical efficiency. An evaluation of farm flexibility sheds light on factors influencing the extent of structural adjustments in the industry, and an analysis of economies of scope provides a basis for understanding sources to improve farm environmental performance.

The analysis covers six EU member states: the Czech Republic, France, Germany, Hungary, Poland and the United Kingdom. The data for the United Kingdom are limited to a sample of farms in England, and French farms are represented by the four most important crop producing regions of the country. The data used are based on the Farm Accountancy Data Network (FADN) provided by the European Commission. Estimations were done separately for two periods covering years before and after the 2003 CAP reform. The measure of TFP growth presented in this report is derived without considering environmental, animal welfare and social aspects of farming. It is derived from farm-level data, and may differ from aggregate sector-level TFP growth estimates.

Crop farm TFP growth was found to show similar magnitudes and patterns during the 1995-2003 period in the three West European countries covered in the report. French and West German sample farms increased their productivity annually at an average rate of 0.7%, while for English sample farms average TFP growth was 0.9% per year. The major source of TFP growth in France and Germany was technical change, pushing out the production possibility frontier, while TFP growth of English crop farms was mainly due to the scale effect.

The productivity trends for the later 2004-13 period were found to be more diverse. While TFP was estimated to grow for English and French farms, it showed a substantial decrease for German crop farms. TFP was found to grow for Czech crop farms, to be near zero for Polish sample farms and decrease for Hungarian farms. Technical change was found to be the major source of productivity growth and considerably higher in this period for French and English farms than in 1995-2003; it was also substantially higher than in any other of the analysed countries. Although estimated separately, TFP growth rates showed similar evolution patterns and magnitudes for West German and East German crop farms. Negative technical change was identified to be the major reason for German farm productivity decline. Those findings suggest that there were some specific and systemic changes in the external environment of German crop farms and should be the subject of a separate investigation. The differences in TFP developments across countries found for the 2004-13 period suggest that country specificities and models of the CAP implementation play an important role in determining crop farm productivity growth.

Technologies currently applied on crop farms were estimated to exhibit substantial economies of scale and therefore favour large-scale operations. However, economies of scale are not fully exploited and there exists room to improve productivity by increasing the scale of production. Given an increased variability of agricultural commodities prices, access to effective instruments of market risk reduction can ease farm decision-making, extend farm planning horizon, and thereby improve farmers' capacities to benefit from economies to scale.

Large farms appear to be in a better position to exploit economies of scale and to invest in productivity-enhancing technologies than small-scale farms. This may explain the increasing gap in TFP growth between farm groups by size in France and England. At the same time, larger farms in France, West Germany and England appear to exhibit larger persistent technical inefficiencies. This latter result suggests that while improving productivity by adopting new technologies and practices, large farms in those countries may persistently fail to improve efficiency with which these technologies and practices are implemented. Management of large farms differ from that of individual farms and may demand additional managerial abilities and skills. It may also require serious adjustments in farm organisational structure.

Farm support payments are found to negatively influence crop farm productivity and efficiency of input use. Farm TFP growth was estimated to be lower and persistent technical inefficiency higher for farms receiving more support payments. This holds if support is measured as total payments per hectare of agricultural land, or alternatively as total payments per farm total output, and controlling for farms located in less favoured areas (LFA) and other farm specificities. More decoupled payments are found to be less distorting for productivity than other forms of support.

No significant economies of scope were found in the analysed crop production systems. This implies the absence of significant cost complementarities between three analysed groups of outputs – cereals, other crops and other farm output including livestock and other agriculture-related activities – in the study countries. The only exception was the English farm sample, for which a significant weak complementarity between cereals and other crops was measured. For two countries, Germany and Poland, significant diseconomies of scope were estimated. However, economies of scope can be present at lower levels of output aggregation and in regional production systems. More systematic research is required to understand the potential for improving local eco-system resilience and productivity by engaging in more integrated production systems.

A meta-level analysis of allocative inefficiencies suggests that allocative inefficiencies with respect to variable inputs use reduced substantially in 2004-13 compared to the 1995-2003 period in the three West European countries analysed in this report. This may be due to a less distortive effect of policies on farm decisions but also reduced downside revenue risk in the presence of decoupled payments. French farms were found to be allocatively efficient in labour use, while English crop farms appear to have optimal size considering English agricultural land rents. Crop farms tend to be over-capitalized. Farm allocative inefficiencies in capital use were found to be considerably higher for England, France and West Germany than for the three East European countries covered by the report. Two potential options for improving capital allocation are: first, facilitating transparent and efficient markets for agricultural machinery and contract services, including collective use of machines in agricultural machinery cooperatives and exchange of services between farmers; second, promoting the development of scalable and flexible technologies and equipment which can be easily adjusted to specifics and requirements of different crops. Both options could encourage farms also to explore advantages of economies of scope and, thereby, increase productivity in a more environmentally sustainable manner.

## 1. Context and scope

Recent OECD work on innovation and productivity in food and agriculture has focused on a range of policy incentives and disincentives that might impact agricultural productivity growth, sustainable use of natural assets such as land, water and biodiversity resources, and mitigation of and adaptation to climate change. In parallel, in collaboration with the OECD Farm-Level Analysis (FLA) Network, the OECD has also analysed farm-level performance and its determinants. The work on agricultural productivity implemented under the 2015-16 PWB builds upon these earlier activities and extends them by evaluating the dynamics and sources of farm productivity growth in crop farms, and analysing the links between productivity growth and farm innovation.

By analysing farm-level data, the report aims to better understand farm behaviour and responses to government policies and changes in their economic environment and to identify actions needed to induce sustainable productivity growth at the farm level.

This report presents and discusses the results obtained from evaluating total factor productivity of crop farms for six European Union (EU) member states – the Czech Republic, France, Germany, Hungary, Poland and the United Kingdom. The analysis is based on Farm Accountancy Data Network (FADN) data as provided by the Directorate-General for Agriculture and Rural Development of the European Commission. The data for France, Germany and the United Kingdom cover the period from 1995 to 2013, making it possible to evaluate the performance of farms in the period after the implementation of two major reforms of the EU Common Agricultural Policy (CAP) – the 1992 and the 2003 reforms.

The MacSharry reform of 1992 scaled down price support and replaced it with direct aid payments to farmers coupled to current-period area and animal numbers. The 2003 CAP reform decoupled direct payments from production and made them conditional on compliance with environmental and other requirements set at the EU and national levels. Although cross-compliance had been in place in many EU member states prior to the 2003 reform, it had been voluntary and applied only to environmental standards. Since 2005, the year when the 2003 reform became effective, EU farmers must respect good agricultural and environmental conditions as well as statutory management requirements, which concern protection of environment, public, animal and plant health, and animal welfare, to be eligible to receive direct payments.

Abolishing intervention prices was anticipated to enforce market orientation and to improve the competitiveness of EU farmers. Given that intervention prices were above world prices, their reductions were expected to decrease production on farms with low levels of productivity and in this way improve the productivity and competitiveness of the sector in the international context. Because guaranteed prices for cereals were lowered by 35%, crop farming was one of the most affected sectors.

Three models of decoupling have been implemented: historical, regional and hybrid models. In the historical model, the magnitude of Single Payment (SP) is determined using farm historical production volumes. The regional model sets the average support based on production history of the agricultural area in the region. The hybrid model uses both regional and historical references. While regional payments are of the same magnitude for all farmers in a region, historic and hybrid model payments vary across farmers. The member states, which joined the EU in 2004 and 2007, implement Single Area Payment Scheme (SAPS) which is similar to the regional model.[1]

Market developments and farmers' expectations about future price trends play a key role in their decisions to invest and to innovate. After a rise in the 1995-96 marketing year, world prices for cereals and other crops were decreasing before showing a steadily increase at a rather moderate rate in the early 2000s (FAO, 2017). After the 2007 price spikes, agricultural commodity prices have stayed quite high compared to their levels between the 1992 MacSharry and the 2003 decoupling reforms. These recent price trends might have positively influenced farm expectations about future price developments. However, agricultural

1. France adopted the historical model, while England and Germany opted for the dynamic hybrid model to move to a flat-rate payment starting from 2012 and 2013, respectively.

commodities have been subject to high volatility in recent years, which might also have influenced farm production and investment decisions.

Innovation is key to improving agricultural productivity sustainably (OECD, 2012; Alston, 2010). A targeted fostering of research and producers' innovations requires knowledge about major sources of productivity growth and factors explaining farm productivity growth. By decomposing farm TFP growth in its components, the report shows which sources of productivity growth were decisive for improving farm performance given the farm external environment including farming policy and economic framework. Measuring the extent of technical change shows the speed of innovation adoption, while evaluating the magnitude of technical efficiency in the industry provides information on the magnitude of innovation diffusion in the sector. Analysing drivers of TFP growth identifies distinctive characteristics of farms shaping current frontier technologies. The report also investigates which factors make farms persistently fail to catch up the frontier technologies.

Both the 1992 and 2003 CAP reforms aimed at increasing EU farm productivity and competitiveness. A stronger orientation of agricultural producers on market signals has been anticipated to cause substantial structural adjustments in the sector and thus induce serious changes in the industry structure. The report examines EU crop farms' technologies for presence of economies of scale and appraises, to which extent adjustments in farm size contributed to productivity growth.

A recent OECD cross-country study on farm size distribution (Bokusheva and Kimura, 2016) revealed a trend towards a stronger polarisation of farm size distribution for a number of the OECD countries: while large farms continue to increase their operations, apparently exploiting economies of scale, a large number of small producers remain in the sector for various reasons. The concept of flexibility provides a reasonable explanation for the coexistence of large and small firms within the same industry. Flexibility is the ability of firms to adjust to fluctuations in demand by switching from one product to another at relatively low cost. The report presents results of an analysis of farm flexibility, evaluates whether small farms show higher degree of flexibility and test for a potential relationship between farm flexibility and productivity.

To evaluate the potential for improving agricultural productivity in an environmentally sustainable manner, the report measures farm economies of scope and test for the presence of weak cost complementarities between the three aggregated farm outputs – cereals, other crops and other farm outputs. If economies of scope exist, multi-output farms will have a cost advantage over specialized farms.

Evaluating producers' decision for the presence of allocative inefficiencies can help to detect potential discrepancies between market allocation mechanisms and regulatory frameworks, and therefore help to appraise the effect of regulations on farm costs. The report evaluates allocative inefficiencies in EU crop farms comparing marginal products of land, labour, capital and materials inputs with respective input prices.

## 2. General framework

TFP measured at the sector level provides the most comprehensive measure of the sector performance. However, TFP growth measured using aggregate data does not provide any information about the distribution of productivity growth and does not allow evaluating sources and determinants of productivity growth. The measure of TFP growth presented in this report is derived using farm-level data. Accordingly, its estimates may differ from aggregate sector-level TFP growth estimates.

Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use (OECD, 2001).[2] This report measures farm-level TFP growth employing the Törnqvist-Theil index and decomposes it to three components – technical change, scale effect and technical efficiency.

2. Accordingly, it differs from the profitability concept which evaluates farm economic performance considering firm's output and input prices. In general, higher productivity does not necessarily result in higher profitability, except the case when firms are maximising profit and there is no allocative inefficiency (Kumbhakar et al., 2015)

**Technical change** embodies the effect of farm innovations on production technology. It can be achieved either through expanding the production possibility frontier for a given set of inputs (producing more output with the same amounts of inputs) or reducing the lower boundary of the input requirement set for a given amount of production output (using less inputs to produce the same amount of output). According to the induced innovation hypothesis (Binswanger, 1974; Hayami and Ruttan, 1985), relative resource scarcity guides technical change towards using resources that are less scarce and thus relatively inexpensive, while saving on scarce and expensive resources. Depending on changes in relative input prices, technical change can take different directions (for example, to be capital-using and labour-saving, or land-saving and material-using etc.).

A technology exhibits increasing (IRTS), constant (CRTS) or decreasing (DRTS) **returns to scale** if a proportionate increase in all inputs results in a larger, equal or less than proportionate increase in output, respectively. The presence of IRTS signals that farms have economic incentives to increase the size of their operations and implies the need for further structural adjustments given an adequate representation of all resources used in the production. DRTS can indicate that either current farm structures are too large, or certain farm outputs might be undervalued. Given that many ecosystem services and externalities from agricultural production are non-market goods and services (and thus are not valued in economic analyses), the evaluation of scale effects requires the use of a broader perspective on agricultural production.[3]

**Technical efficiency** measures how efficiently farms use their resources given the existing technology. It reflects the ability of a farm to obtain the maximum output from the resources at its disposal, i.e. output-oriented technical efficiency, or to produce a given output level from a minimum set of inputs, i.e. input-oriented technical efficiency. The technical efficiency component shows the potential for improvements in productivity from eliminating redundancies in input use, compared with the best observed practice in the industry. The speed and extent of innovation diffusion determines the magnitude of efficiency catch-up. Therefore, examining changes in technical efficiency and TFP estimates can provide valuable insights on agricultural innovation system (AIS) performance.

In this report, technical efficiency – the overall technical efficiency – is seen as composed of two parts, **persistent technical efficiency and transient technical efficiency** (Kumbhakar and Tsionas, 2012; Kumbhakar et al., 2012). While a farm's transient technical efficiency may change from one period to another, the persistent technical efficiency remains constant for each producer over a long period of time and thus captures systematic management failures to improve efficiency of resource use. Given that persistent technical efficiency is time-invariant, the technical efficiency component of TFP growth refers only to changes in transient technical efficiency. To understand why some farmers may systematically fail to use their resources efficiently, the report evaluates the determinants of persistent technical inefficiency.

**Allocative efficiency** reflects the ability of a firm to use the right combination of inputs (input allocative efficiency) or to produce the right mix of outputs (output allocative efficiency) given the set of prices. An allocatively efficient farm chooses outputs and inputs in combinations that maximise its profit at given prices. If deviations from optimal behaviour have a systemic character, i.e. have the same pattern for all study units, this might indicate the presence of regulations or deficiencies in the farm external environment which hinder optimal allocation of resources given current market prices. Alternatively, if allocative efficiencies vary from farm to farm, i.e. have an idiosyncratic character, this might point to problems in individual farm management. Environmental cross compliance presents an important regulation in the EU agriculture. Given

3. The concept of returns to scale is very close to the concept of returns to size. "Economies of size" is a more general concept capturing the possibility to increase productivity by exploiting economies of scale and additionally through adjustments in input composition. The two measures are identical in the case of a homothetic technology, that is when proportional increases in all inputs are of the same magnitude as the change in the aggregate input use (Chambers, 1988). The analysis presented in this report measures economies of size but calls them economies of scale as it is common in the productivity analysis literature (Coelli et al., 2005; Kumbhakar and Lovell, 2004). Consequently, while referring to economies of scale, the report considers both proportional and non-proportional adjustments in farm input use.

that most environmental goods and services are non-market goods and are not subject to market valuation, farm costs might have inflated since environmental cross compliance implementation.

Allocative inefficiencies may also manifest **the effect of risk** and risk aversion on farmers' production decisions. In the absence of risk, expected utility maximisation implies cost minimisation (Chavas, 2004). At the optimum, farm marginal output supply is equal to the farm marginal cost. However, the farm supply moves from the optimum to a point where the expected output price exceeds marginal costs under price uncertainty and risk aversion. Accordingly, marginal cost pricing does not apply anymore and farm input use may be suboptimal compared to riskless environment. The MacSharry reform and recent developments in the markets for agricultural commodities increased the effect of market risk on farm decisions. Therefore, it can be anticipated that these changes in the external environment of EU crop farms may have induced farmers to produce at costs exceeding marginal costs by costs of private risk bearing and respectively have lowered farm productivity. Given that larger farms might be less risk averse, better suited to manage risks on farm and have a better access to markets for financial risk management, the effect of an increased market risk might have been lower for them than for small-scale farms. While increasing farmers' income by a constant amount, decoupled direct payments may have damped the effect of market risk on farmers' production decisions, since relative risk premium reduces with increases in initial wealth for a (downside) risk-averse farmer. The magnitude of this effect depends on the extent of market risk, farmers' risk aversion and availability of instruments for market risk management.

**Economies of scope** are another important source of agricultural productivity growth at the farm level. Economies of scope (diseconomies of scope) are situations where it is less costly (more costly) to produce the aggregate outputs from an integrated firm as compared to specialised firms (Baumol et al.,1982). Existence of scope economies is primarily explained by cost complementarities, i.e. situations when firms/farms can save costs by using their resources to produce multiple outputs. Chavas and Kim (2007) introduced a more general formulation of economies of scope. According to these authors, economies of scope exist when producing multiple outputs in an integrated manner increases productivity. In addition, Chavas (2008) draws attention to complementarities that may arise as a result of positive externalities from diversified production systems. In this context complementarity is a factor contributing to both biodiversity and agro-ecosystem productivity. Examining agricultural production systems for economies of scope is relevant for identifying synergies or complementarities that might exist across production activities. These may arise from more efficient use of resources in a multi-output production system or from increases in soil productivity and better control of pest populations (for example, because of more extensive crop rotations). An increased market risk might also have induced farmers to engage in more diversified production systems.

Specialised farms can benefit from economies of scope when separate production of two output groups shows diseconomies of scale and cost savings due to economies of scope can compensate decreasing economies of scale in production of these output groups. In this situation, integrated production would increase scales of farm operations and simultaneously improve farm cost efficiency (productivity). However, specialized production will tend to have cost advantages over diversified production systems in the presence of diseconomies of scope. If no economies of scope exist, then scale economies for a farm are just the weighted average of the product specific economies of scale for farms specialising on single products. On the other hand, if an integrated production system shows IRTS (implying that its scale is too small), then economies of scale will have a positive effect on economies of scope. Under DRTS, economies of scale will negatively affect economies of scope (productivity of an integrated production) and induce higher levels of specialisation, while under CRTS, scale economies will have no effect on economies of scope (Chavas and Kim, 2007).

The concept of **flexibility** explains in which situations small-scale farms can be as cost efficient as their larger counterparts (Stigler, 1939). Flexibility is defined in terms of firms' cost curves: the flatter the curvature of the average total cost curve, the greater the firm's flexibility. Empirical studies for agriculture reveal that, in fact, the curvature of the average cost curve measured for different types of farms does not follow the standard convexity assumption in production economics, but stays flat for farms of different sizes (for example, Lund and Price, 1998).

Cremieux et al. (2005) developed a measure of a multi-output firm flexibility, which can be calculated using a flexible cost function. This measure is based on the concept of ray average cost and consists of three terms corresponding with the effects of scope, convexity and scale. The first term refers to cost saving which can be achieved in the presence of economies of scope. The second is related to the curvature of the cost function: lower levels of the convexity term correspond with higher flexibility and signal that current technologies compensate/release to a certain extent resource scarcity. The third term captures the effect of economies of scale. In general, lower values of the flexibility index correspond with higher farm flexibility. Therefore, while small-scale firms may be more flexible due to the convexity effect and the effect of economies of scope, larger farms may show higher flexibility due to scale efficiency. Hayargasht et al. (2008) showed how economies of scope can be derived using a flexible form of an input distance function. Elaborating on results of the both above-mentioned studies, Renner et al. (2014) derived a primal measure of flexibility for a multi-output production technology.

To be able to model a multiple-output multiple-input technology and to account for stochastic nature of crop production, the analysis is conducted employing a stochastic input distance function (IDF). An input distance function measures the maximum amount of input by which input use can be radially reduced but be still feasible to produce a given vector of output (Shephard, 1953). The translog functional form was used to model the input distance function with three outputs (cereals output, other crops output and other farm output) and four inputs (land, labour, capital and materials). The IDF can be used to measure and decompose TFP growth (Karangiannis et al., 2004). Given the dual relationship between cost function and IDF, the latter also allows to derive cost flexibility and economies of scope – two concepts, which exploit certain properties of the cost function. Another advantage of the IDF approach is that optimality conditions for cost-minimising behaviour (input use) can be derived even in the absence of price data. A detailed description of the methodology applied can be found in Annex A.

Given the absence of relevant data and that the methodological framework for evaluating **farm environmentally-adjusted TFP** measure is still evolving, the analysis uses the traditional definition of productivity growth, which does not account for environmental, animal welfare and social consequences of farm production decisions. However, by measuring economies of scope between three aggregated farm outputs, the analysis evaluates options for improving environmental and economic performance of crop farms that can be achieved through improvements in ecosystem productivity by engaging in more integrated production systems. Yet, it is beyond the scope of the report to investigate whether cost advantages which can be achieved through economies of scope may be scaled up by increasing farm input use and to derive any further implications for environmental impacts of farm production decisions.

**The effect of policy** on farm production decisions and productivity can be evaluated either by modelling shifts in technology parameters due to a reform and testing respective model parameters and indicators derived on their basis for statistical significance. Another way to evaluate the effect of policy is to measure the effect of subsidies[4] on indicators of farm performance. Given that the EU FADN 1992-2009 and 2010-13 samples are formed using different farm typologies, the application of the first option is rather complicated due to a short period covered after the 2003 decoupling reform in the 1992-2009 sample and farm sampling rotation practices applied in the FADN system. Therefore, the second option was applied. Four measures of subsidies were considered: total subsidies per hectares of Utilised Agricultural Area (UAA), total subsidies to farm output ratio, decoupled payments per hectares of UAA and coupled payments per hectares of UAA.[5]

In general, **subsidies** have several channels through which they may influence farm productivity. Subsidies may negatively influence sector performance by distorting output and factor market prices thus

4. The terms ‘subsidies’ and ‘decoupled payments’ are used in this report in the sense of the FADN data; variables SE605 and SE630, respectively.

5. Given that coupled and decoupled payments are anticipated to show strong negative correlation over time (decrease in coupled subsidies was accompanied with an increase in decoupled payments), their effects were estimated separately only in the model of persistent technical inefficiency, which does not consider temporal changes in indicators.

making farms deviate from optimal resource allocation and causing substantial allocative and technical inefficiencies. Subsidies may also provoke situations referred to as soft-budget constraints (Kornai, 1986), when chronically loss-making farms may decide to stay longer in business due to weaker financial pressure in the presence of regular financial influxes in the form of subsidies. By relieving some market imperfections, subsidies may also positively influence farm productivity. In particular, by lessening farm credit constraints (Bezlepkina et al., 2005), subsidies may improve farms access to innovative technologies and thus speed up technical change. As already mentioned, subsidies may also reduce resource misallocations in the presence of risk and risk aversion. Finally, subsidies can influence farm productivity when they are conditioned on environmental cross-compliance. The overall effect of subsidies depends on the presence and the magnitude of the above-mentioned effects. In general, decoupling producer support from production can be anticipated to have reduced distorting effects of subsidies on EU farm decisions and thus positively influenced farm productivity and competitiveness.

## 3. Data

To measure and decompose TFP growth, panel (longitudinal) data are required. FADN data for two periods – 1995-2003 and 2004-13 – were used for France, Germany and the United Kingdom (UK). For the Czech Republic, Hungary and Poland, FADN data are available only for the 2004-13 period.[6] Given that the 1995-2003 and the 2004-13 FADN farm samples are formed using two different farm typologies, i.e. the Standard Gross Margin (SGM) and the Standard Output (SO) typologies, the input distance function models were estimated separately for the 1995-2003 and 2004-13 samples. Consequently, model estimates were analysed and presented separately for these two periods, and direct comparisons of results between the two periods should be done with care.

Although the 1995-2003 data cover all 16 German federal states, the input distance function was estimated only for West German farms for this period in order to compare the results with those obtained for sample farms in France and the United Kingdom (England).[7] For 2004-13, IDFs were estimated separately for East and West German farms to account for differences in farm structures.

Country samples of study farms consist of specialised cereals, field crops, mixed crops, and mixed crops and livestock farms[8] according to the FADN farm typology.[9] The data for the United Kingdom are limited to a sample of farms in England. For France the analysis was done for the country most important crop producing regions showing similar natural and climatic conditions as regions in the other five study countries: Île de France, Bassin parisien, Nord-Pas-de-Calais and Est.[10] Given specifics of sugar market regulations in the

6. Although these three study countries joined the EU in 2004, the actual process of integration began much earlier: Hungary and Poland applied for EU membership in 1994; the Czech Republic in 1996. Adjustments in national agricultural policies to the EU CAP also took place already in the period prior the EU accession.

7. The IDF model was estimated separately for East Germany for 1995-2003 though. However, model parameter estimates were found not to be theoretically consistent for this sample. Consequently, the analysis for 1995-2003 is done without considering East German sample farms. Inconsistencies in model estimates for East German sample farms may go back to serious changes in farm organisation and bookkeeping which took place after the reunification of the country and might have influenced technologies and practices applied on East German farms as well as farm data in the mid-1990s.

8. Mixed crops and livestock farms are less specialised on crop production compared to other three types covered in the analysis. However, these farms have to generate more than one-third of the SO (SGM prior to 2004) from crop production to be classified as mixed crops and livestock farms.

9. Please consult http://ec.europa.eu/agriculture/rica/ for more details on FADN farm typology and the measurement of single FADN indicators/variables.

10. Lower Normandy was excluded from the Bassin parisien, and Alsace and Vosges from the Est region.

European Union, farms with more than 10% of their total crops area allocated to sugar beet were excluded from the analysis. Only farms with positive values of model inputs and outputs were considered.

Panel data sets were generated by keeping in the samples only farms with at least 5 consecutive years of observations.[11] This procedure was employed to address the problem of endogeneity that is to get unbiased and consistent parameter estimates using an appropriate estimation method.[12] The sample sizes after applying selection criteria described above and the final sample sizes are presented in Table 1. They show that the application of this procedure caused a substantial reduction in the sample sizes. Consequently, the analysis performed cannot be considered as representative for the whole population of crop farms in any country; but it allows making empirical inferences into the sources and determinants of productivity growth from data for relatively large samples of farms.[13]

**Table 1. Study country sample sizes**

| Country | Total number of observations | | Percentage of final sample observations in the initial sample |
|---|---|---|---|
| | Initial FADN sample (selected farm types)[1)] | Final sample (5-consecutive-years criteria) | |
| **1995-2003** | | | |
| France | 11 100 | 7 850 | 71% |
| West Germany | 11 900 | 6 921 | 58% |
| England | 5 691 | 2 671 | 47% |
| **2004-13** | | | |
| France | 9 633 | 6 933 | 72% |
| West Germany | 12 846 | 6 752 | 53% |
| East Germany | 7 526 | 4 764 | 63% |
| England | 4 284 | 2 118 | 49% |
| Czech Republic | 5 746 | 3 090 | 54% |
| Hungary | 7 004 | 4 084 | 58% |
| Poland | 26 240 | 8 339 | 32% |

*Note*: 1) Sample size after the selection of relevant farm types, the exclusion of farms with sugar beet crop area above 10% of the farm crop area and the removal of observations with zero values of input and output variables.

11. For Poland the FADN sample farms with observations for at least 6 consecutive years were selected to account for potential measurement errors which might arise in the context of small-scale family farms which may have reduced farm accounting.

12. The endogeneity arises when one or more explanatory variables correlate with the model error term. It may occur in the presence of unobserved heterogeneity of farms, simultaneity and measurement errors in an explanatory variable. For example in the framework of this analysis, endogeneity may occur because of simultaneity in farm input decisions, technical efficiency and technical change.

13. The t-Student mean-comparison test was conducted to test statistical significance of the differences between the means of the two samples – the unconstrained sample and the one consisting of farms with 5-year consecutive observations (6 years for Poland). The test was performed for the following indicators of farm size and productivity: aggregate farm output, land input, and land, labour, capital and materials productivity. Although in most cases the zero hypothesis of no difference in means was rejected by the t-test, no substantial differences between mean values for these two samples were found for any country and period. In addition, deviations in mean values did not show any particular pattern for any country and period – mean values for some indicators in the final samples were larger and for some other indicators lower than in the unconstrained sample.

The vector of output consists of cereals output ($y_1$), defined as the value of farm cereals production; other crops output ($y_2$), measured as the difference between the value of total crops output minus cereals output; and other farm output ($y_3$) calculated as the difference between the value of farm total output and the value of total crops output.

The vector of inputs comprises materials ($x_1$), defined as total intermediate consumption (the sum of farm total crop and livestock production specific costs and total farming overheads) excluding contract work; land ($x_2$), expressed in hectares of farm Utilised Agricultural Area (UAA); labour ($x_3$), measured in numbers of Annual Work Units (AWU) covering both paid and unpaid labour;[14] and capital ($x_4$), calculated as the sum of capital depreciation and expenditures on contract services.[15]

Monetary variables – farm outputs and materials and capital inputs – were deflated using country agricultural producer price indices from Eurostat (Eurostat, 2016). The price index for cereals, crop output in total (excluding fruits and vegetables) and agricultural goods output were used to deflate the cereals output, other crops output and other farm output, respectively. The price index for machinery and other equipment was used to adjust the capital input to the reference year price levels, whereas the price index for goods and services currently consumed in agriculture was employed to deflate materials. Purchasing power price index was used to deflate wages, while agriculture total input price index was used to adjust values of land rents.[16] Data for 1995-2003 were deflated to the 2000 price level, and data for 2004-13 were deflated to the 2010 price level.

A number of additional variables were used as instruments and to explain variation in TFP growth, persistent technical inefficiency, farm flexibility and the magnitude of economies of scope. Description and summary statistics for these variables, as well as for the input distance function output and input variables, are presented in Annex Table B.1.

14. Including operator and family labour.

15. Depreciation as a measure of capital input is routinely used in production analysis (Kazukauskas et al. 2014, Renner et al. 2014 or Cechura et al. 2017). Analogue to Renner et al. (2014) it is assumed in this analysis that both depreciation rate and expenditures on capital services are proportional to the value of capital stock used in the production process, independently of that in whose property it is (for the discussion on the measurement possibilities of the capital input see for example Coelli, 2005). As contract services are frequently used by small farms, it would be interesting from a policy perspective to consider them separately in the analysis. However, many farms do not use contract services and would have zero values for this input. On the other hand, some farms have zero values for capital input. This might have caused serious computational problems and result in biased parameter estimates of the IDF model. To avoid this situation, a model specification with one common capital input variable was used.

16. Agricultural land rents may not be negotiated each year. However, FADN data contains no information on the timing of rent adjustments. Accordingly, to adjust land to real prices, they were deflated on an annual basis. As no price index exists for land rents, the price index for agriculture total input was employed. Assuming that farm land rents are determined by expectations about net revenues from agriculture, the use of agriculture total output index would be an alternative. However, agricultural commodities prices showed very high variations since 2007, therefore using this index might have introduced a bias in real land rents trends.

## 4. Results[17]

### *4.1. Production and technology structure*

Table 2 summarises distance function elasticities with respect to single outputs and inputs.[18] They are derived assuming that farms optimise their production and input use with respect to shadow prices which might differ from market prices. Distance function elasticities with respect to outputs are referred to as shadow shares of outputs in total farm output, while distance function elasticities with respect to inputs are interpreted as shadow shares of inputs in farm total input. Both allow to evaluate the structure of technology used on sample farms. Table 2 also presents estimates of economies of scale. A value larger than 1 indicates that sample farms exhibit increasing returns to scale that is a 1% proportional decrease in all inputs would cause a lower than 1% proportional decrease in the total output.

According to the model results, crop farms' output in France and England show a very strong specialisation on cereals. In both periods the share of cereals in the total output was above 50% as evaluated at the sample means and adjusted to the situation with constant returns to scale to enable comparisons across countries and over time. West German and English sample farms appear to have relatively large shares of other crops. The shadow shares of the third output were found to be highest for the East German and Czech samples and of approximately the same magnitude for other country samples for 2004-13 as evaluated at sample averages. The model estimates indicate considerable differences in the output composition between the samples for two analysed periods for West European study countries. The share of cereals in the second period French sample was lower than in the 1995-2003 sample. The shares of other crops were estimated to be considerably higher for all three country samples for 2004-13 compared to 1995-2003. The share of the other farm output did not change for French 2004-13 sample farms but decreased substantially for West German and English sample farms for 2004-13 compared to respective sample estimates for 1995-2003. These differences in output shares might refer to real changes in farm production structure but also have been caused by changes in the FADN sample composition in 2010 due to the switch to the Standard Output based farm typology.

The cereals shares are comparatively low for East German and Czech farms and are close to the one of West German farms. The structure of output in Hungarian and Polish sample farms shows more similarities with output compositions in France and England due to a high share of cereals. These findings suggest differences in crops relative prices across the EU. Apparently cereals prices are higher compared to prices of other crops in France, England, Hungary and Poland than in Germany and the Czech Republic in relative terms.

Materials input was estimated to have the largest shadow shares in total input for all country samples. They were found to be of an approximately same magnitude (0.48-0.52) for French, West German and English 1995-2003 samples. The materials shadow share is measured to be also similar for the 2004-13 period for French and West German samples. However, it was estimated to be considerably higher for the English 2004-13 sample. East German sample farms also obtained a quite high materials share estimate. The estimation results for East-European member states show that the materials share varied between 0.50 (sample for Poland) and 0.72 (sample for the Czech Republic). Considering the average agricultural area operated by farms in single country samples (Annex Table B.1), model results indicate that large-scale farms tend to have higher materials input shares compared to small-scale operations. This finding suggests that large farms are in a better position to deploy appropriate amounts of fixed factors of production such as capital input given current level of technology development.

17. Sample averages were computed as arithmetic means over all sample observations – no weights were applied. Panel estimators admit using constant weights for units of the analysis. Given that FADN weights and other variables as farm size in UAA or farm output vary over time, no weights were applied in the model estimations.

18. Estimates of input distance function parameters by periods and countries are presented in Annex Table B.2 and are summarised in Annex B (section "IDF parameter estimates").

Among fixed inputs, labour was found to have the second highest shadow share in the total input for all countries except East Germany where farms tend to use more capital intensive technologies. The shadow share of capital was found to be the highest for French, East German and Hungarian sample farms. The lowest marginal productivity of capital was estimated for Czech sample farms. Land shares tend to be higher for sample farms with relatively large shares of cereals.

Technical change was found to be capital-using in France and England in the 1995-2003 period. It was land-using and labour-saving in France, and labour-using in West Germany in the second period according to the IDF model estimates. Technical change was biased towards labour in Hungary and capital in Poland in 2004-13.

**Table 2. Shadow output and input shares: Country samples' average estimates[1]**

France, West Germany and England, 1995-2003 and 2004-13

| Output/input | France | | West Germany | | England | |
|---|---|---|---|---|---|---|
| | 1995-2003 | 2004-2013 | 1995-2003 | 2004-2013 | 1995-2003 | 2004-2013 |
| Cereals | 0.47 (0.62) | 0.43 (0.54) | 0.30 (0.41) | 0.29 (0.40) | 0.42 (0.52) | 0.45 (0.54) |
| Other crops | 0.10 (0.13) | 0.17 (0.21) | 0.11 (0.16) | 0.22 (0.31) | 0.15 (0.19) | 0.21 (0.26) |
| Other output | 0.19 (0.25) | 0.19 (0.25) | 0.31 (0.43) | 0.21 (0.29) | 0.24 (0.30) | 0.17 (0.20) |
| Materials | 0.52 | 0.51 | 0.50 | 0.51 | 0.48 | 0.57 |
| Land | 0.11 | 0.13 | 0.14 | 0.13 | 0.13 | 0.17 |
| Labour | 0.22 | 0.20 | 0.24 | 0.25 | 0.21 | 0.16 |
| Capital | 0.16 | 0.16 | 0.12 | 0.10 | 0.19 | 0.10 |
| Economies of scale | 1.31 | 1.27 | 1.37 | 1.39 | 1.24 | 1.21 |

East Germany, Czech Republic, Hungary and Poland, 2004-13

| Output/Input | East Germany | Czech Republic | Hungary | Poland |
|---|---|---|---|---|
| Cereals | 0.35 (0.41) | 0.36 (0.38) | 0.44 (0.49) | 0.33 (0.49) |
| Other crops | 0.26 (0.30) | 0.31 (0.33) | 0.26 (0.30) | 0.17 (0.25) |
| Other output | 0.26 (0.30) | 0.28 (0.29) | 0.20 (0.22) | 0.18 (0.26) |
| Materials | 0.65 | 0.72 | 0.56 | 0.50 |
| Land | 0.07 | 0.07 | 0.15 | 0.09 |
| Labour | 0.12 | 0.13 | 0.12 | 0.31 |
| Capital | 0.16 | 0.07 | 0.18 | 0.10 |
| Economies of scale | 1.16 | 1.04 | 1.11 | 1.47 |

*Note*: 1) Derived as input distance function elasticities for respective outputs and inputs. Output shadow shares are measured as negative values of first order derivatives of the input distance function with respect to single outputs; values in parentheses are output shadow shares evaluated at constant returns to scale (to sum up to 1) by normalising single output elasticities by corresponding estimates of economies of scale.

The sample average estimates of economies of scale presented in the last row of Table 2 indicate that technologies applied on farms appear to exhibit considerable economies of scale. Unexploited economies of scale appear to be substantially higher in West European countries, in particular West Germany. The Czech, East German and Hungarian sample farms tend to be closer to optimal scales of production with Czech crop farms operating at almost constant returns to scale as evaluated at the country sample average. High magnitudes of economies of scale estimates indicate that EU crop farms analysed in this report have a substantial potential to improve their productivity by increasing scales of operations.

### *4.2. TFP growth estimates*

TFP growth was found to be growing at very moderate rates for farms in the three West European study countries during the 1995-2003 period (Figure 1). TFP changed annually on average by 0.7% for French and West German sample farms and by 0.9% for English sample farms in this period (Table 3). These findings are consistent with USDA productivity estimates at the sector level, which revealed a steady – although moderate – growth in EU agriculture for the period after the implementation of the MacSharry 1992 CAP reform (Ball et al. 2010).[19] For all three countries the scale effect positively contributed to the TFP change according to the TFP decomposition results. The scale effect was estimated to be the largest and represent the main source of TFP growth for English sample farms as evaluated at the sample averages. Technical change was found to be positive for all three West European farm samples analysed, however, very negligible for England in the first period. Though very moderate, technical change was measured to be the major source of productivity growth for France and Germany. Technical efficiency was not found to have any serious changes in the 1995-2003 period.

TFP change was estimated to be substantially higher for English and French crop farms in the 2004-13 period, 1.7% and 1.1%, respectively. With average annual rates of 2.4% and 1.3%, in the England and France, respectively, technical change was the driving force of farm productivity growth as evaluated at the sample averages in both countries. The scale effect was assessed to negatively contribute to TFP growth in England and France on average over the 2004-13 period. Technical efficiency was not found to show any changes for French and English sample farms. TFP change was assessed to be negative for the 2004-13 sample for West Germany. All three components of TFP showed negative growth rates for West German sample farms on average in this period. An overall negative scale effect, decreasing technical efficiency and negative technical change caused an average TFP decrease by 0.8% annually in West German sample farms in 2004-13. The average annual rate of TFP change was estimated to be negative also for East German sample farms: -1.0% per year on average. Though estimated separately, productivity growth shows very similar patterns for both parts of the country. This implies that there might be some systemic changes in the external environment of German farms in this period which provoked substantial drops in crop farm productivity. It might have been due to changes in policies and regulations, but also due to changes in farm accounting. With -1.3% per year on average, the major reason for the TFP decline in East Germany – similar to West Germany – was a decreasing technical change. A negative rate of technical change implies that farm costs were growing faster than their revenues. Although positive, the scale effect was measured to be too small for East German farms (0.3% per annum on average) to compensate the negative effect of technical change between 2004 and 2013. However, its effect was very uneven over this period. Technical efficiency effect evaluated at the sample averages was varying over the period, but was estimated not to affect TFP evolution in the longer run for East German sample farms.

19. However, in contrast to the findings by Ball et al. (2010), who estimated the UK agriculture TFP growth lagging productivity growth in other European countries, the TFP growth for English sample farms was found to be slightly higher than for the French and West German sample farms in the report. This difference in results between two analyses may be explained by the fact that the report examines productivity of crop farms exclusively, while the study by Ball et al. (2010) measures productivity growth of the whole sector. The outbreak of Bovine spongiform encephalopathy (BSE crisis) seriously affected the performance of the UK livestock farms in the 1990s which definitely had an impact on the UK agriculture productivity development in this period.

Czech sample farms productivity is assessed to have grown annually on average by 0.7% in the 2004-13 period, whereas Polish farms have improved productivity annually on average by only 0.1%. Technical change was the major source of sample farms productivity growth for the Czech Republic as well as Poland. A higher TFP change for Czech study farms was also due to improvements in technical efficiency. A negative scale effect hindered Polish sample farms achieve higher productivity growth as evaluated at the sample averages. TFP change was estimated to be negative for Hungarian sample farms. All three TFP components were found to contribute negatively to TFP growth for Hungarian sample farms.

**Table 3. TFP change decomposition results: 1995-2003 and 2004-13 period samples' averages**

| Country/ periods | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| **1996-2003** | | | | |
| France | 0.007 | 0.005 | 0.002 | 0.000 |
| West Germany | 0.007 | 0.006 | 0.002 | -0.001 |
| England | 0.009 | 0.001 | 0.009 | -0.001 |
| **2005-2013** | | | | |
| France | 0.011 | 0.013 | -0.002 | 0.000 |
| West Germany | -0.008 | -0.005 | -0.002 | -0.001 |
| East Germany | -0.010 | -0.013 | 0.003 | 0.000 |
| England | 0.017 | 0.024 | -0.008 | 0.002 |
| Czech Republic | 0.007 | 0.004 | 0.000 | 0.003 |
| Hungary | -0.004 | -0.002 | -0.001 | -0.001 |
| Poland | 0.001 | 0.003 | -0.003 | 0.000 |

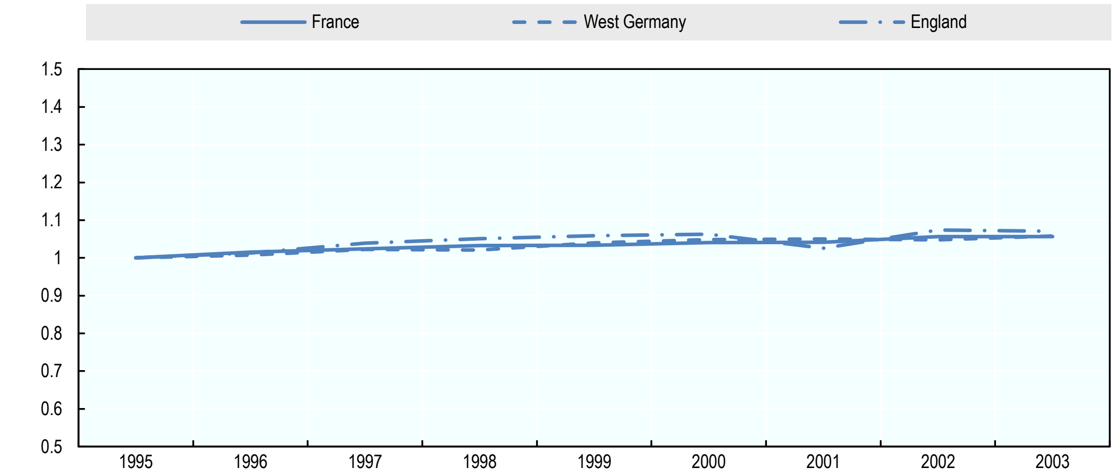
1. For the technical efficiency component positive values indicate improvement of technical inefficiency while negative values correspond with a decrease in technical efficiency.

TFP trends presented in Figure 1 demonstrate that crop farm productivity was increasing in England, France, West Germany and in the period 1995-2003 approximately at the same – although rather moderate – rates and showed similar patterns. In the period 2004-13, country productivity trends show different developments across the three West European countries analysed. Crop farm productivity was continuing to increase and even at higher rates than in the earlier period in France and England, whereas West as well as East German farms showed a substantial TFP decrease. The TFP trend estimated for Czech sample farms has a similar pattern as those for the French and English samples, while annual average TFP estimates for the Hungarian and Polish samples show substantial variation over time. These results suggest that country specificities and models of the 2003 CAP reform implementation play an important role in determining farm productivity growth.

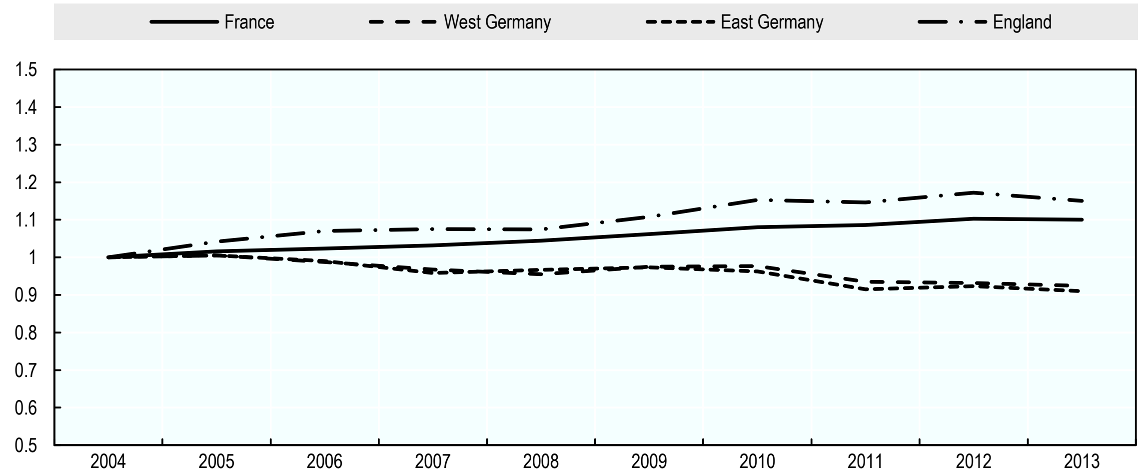
Annual sample average estimates of TFP growth components presented in Table B.3 show that aggregate scale effect estimates show considerable variation and often changed their sign from positive to negative and backwards across single years for the 2004-13 period. The variation in the scale effect was found to be particularly distinct for countries assessed to show high economies of scale in crop production. Since in general farmers are assumed to maximize profits, recent price developments may have encouraged them to increase production. However, due to high price fluctuations these adjustments may not necessarily have resulted in anticipated margins forcing farms to repeatedly revise their production decisions. This variation in scales of operations can be an explanation for the variation in annual scale effect estimates.

**Figure 1. TFP evolution: Country sample average estimates**

France, Germany and England, 1995-2003 (1995=100)




France, Germany and England, 2004-13 (2004=100)




Czech Republic, Hungary and Poland, 2004-13 (2004=100)

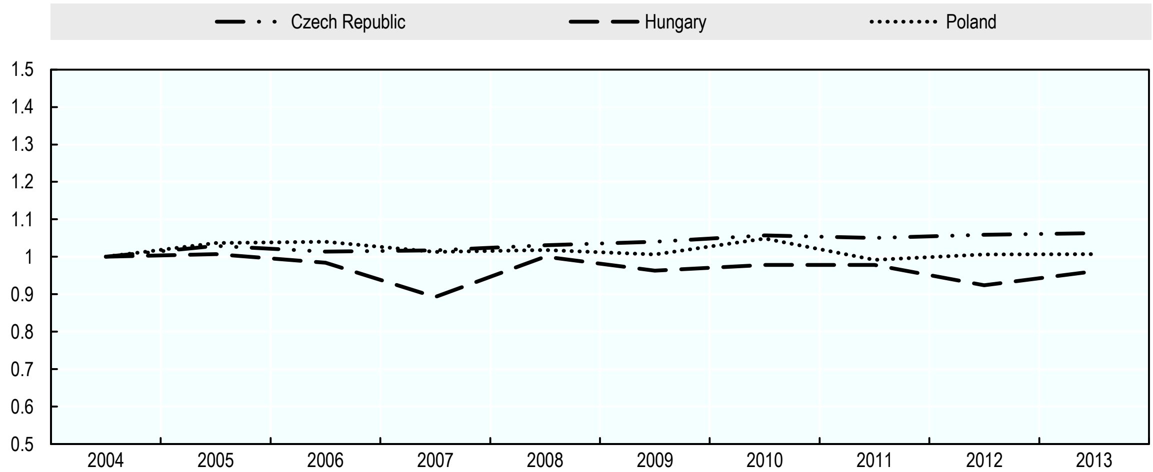
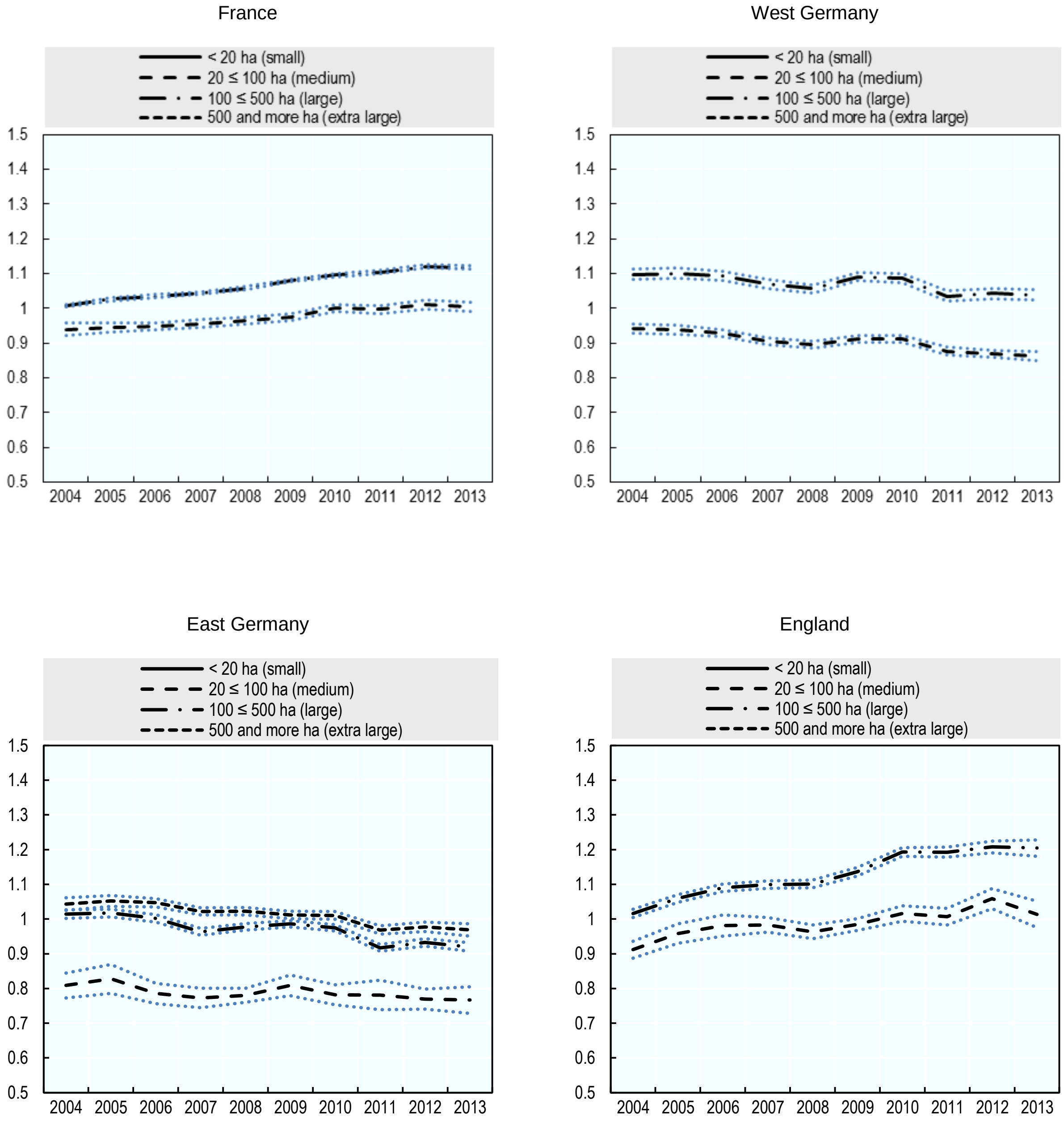
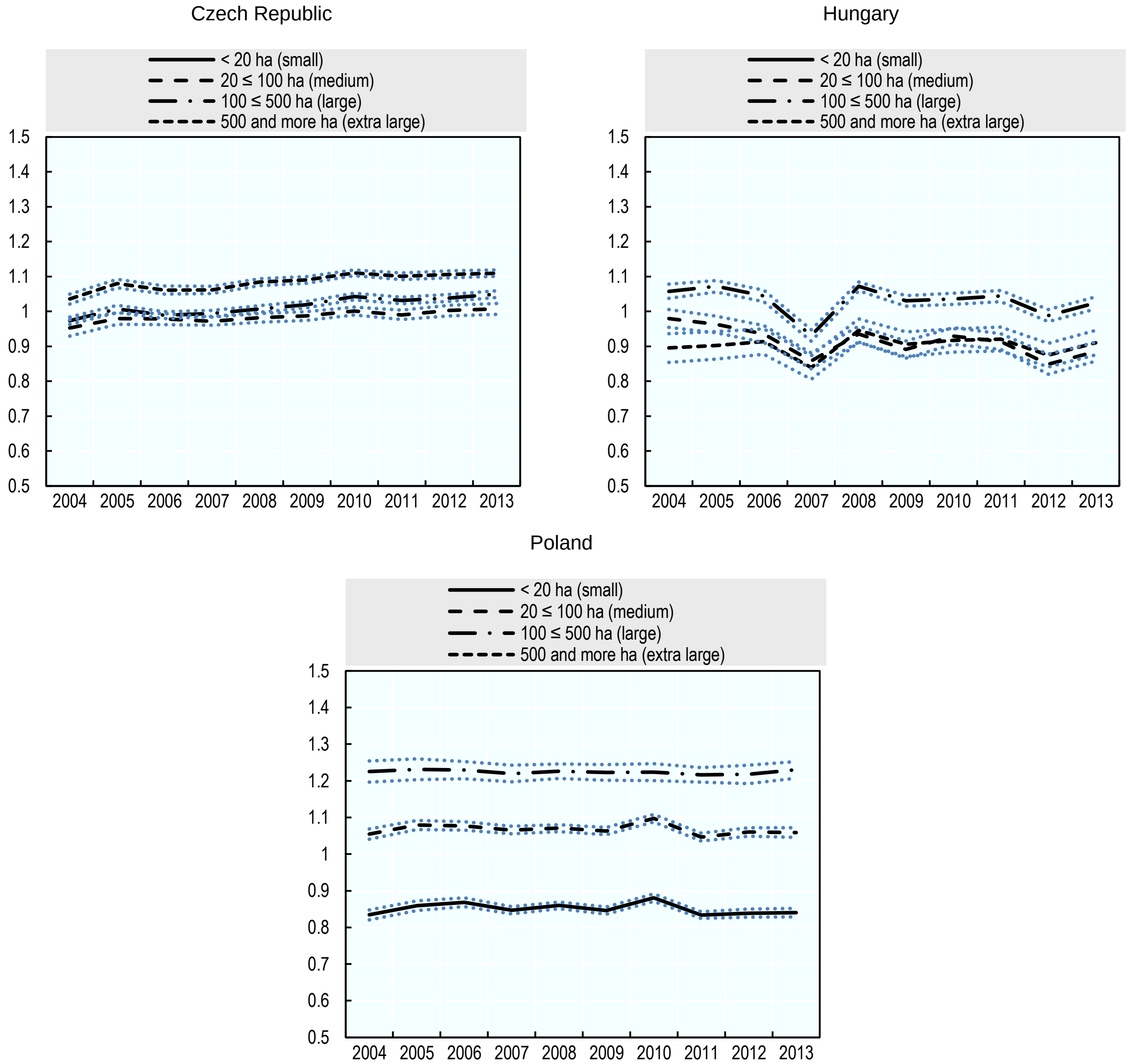


**Figure 2. TFP evolution by farm size: Average estimates and respective 95% confidence intervals, 2004-13 (sample average in 2004=100)[1]**






*1.* Blue dashed lines show 95% confidence intervals for TFP growth mean estimates for farm groups by farm size. They were computed to account for the variation in TFP growth estimates within groups and the number of observations used to derive groups' means. This procedure was used only for groups of farms with the number of observations sufficiently large to obtain plausible estimates.

TFP trends for country samples calculated for different farm size groups presented in Figure 2 show that larger farms tend to be more productive than smaller farms across evaluated farm groups. This is obviously due to the effect of increasing returns to scale, although technical change may also have played a role. While being already closer to optimal size, larger farms may exploit economies of scale more efficiently as they tend to be less risk averse, and have stronger bargaining power, better access to external finance and innovations. The latter may explain an increasing gap in the productivity of large and medium farms found for the farm samples for France and England where technical change was increasing fastest across analysed countries in the 2004-13 period. However, for the Hungarian sample, farms of the size above 500 hectares of UAA were found to have lower TFP growth rates than farms operating between 100 and 500 hectares of UAA.

### *4.3. Determinants of farm TFP growth*[20]

An analysis of TFP growth determinants was performed using two specifications of a random effects (RE) Tobit model.[21] The first model specification employs the subsidy variable measured per hectare of UAA (Table 4), while the second specification utilises the subsidies to farm output ratio (Annex Table B.4) to measure the effect of subsidies on farm productivity growth.[22] In the following the discussion is focused mainly on the estimates obtained using the first model specification, while results from the second specification are used for validating the results of the first specification. If significant, the effect of subsidies on farm TFP growth was found to be mainly negative for all three West European study countries. This applies for West German sample farms in the first period and French and East German sample farms in the second period of the analysis. The effect of subsidies on farm TFP growth was estimated to be significant and negative for all three East European study countries. When measured per farm output, the total subsidy variable obtained a highly significant negative estimate for all study countries (Annex Table B.4).

The estimates of the TFP determinants model support the results presented earlier and indicate that larger farms showed a significantly higher productivity growth in all country samples. The farm size variable obtained highly significant and positive estimates for all country samples except the Hungarian one. Also farms which search for options to expand their size by renting land and employing paid labour input are found to show higher productivity growth rates.[23] These results suggest that larger farms appear to be in a better position to exploit economies of scale and to invest in productivity-enhancing technologies than small-scale farms. Expressing farmer's experiences, the farmer's age variable shows a positive influence on productivity growth if significant.[24] Farm organisation in the form of a partnership or a corporate farm was found not to be decisive for TFP growth of English sample farms, whereas it was estimated to be significant for West German sample farms for the first period. Given that this variable shows a strong positive correlation with rented land share and had to be removed from the model for France, East Germany, the Czech Republic and Hungary,[25] it

20. The number of observations differ across the models specified to evaluate determinants TFP growth, persistent technical inefficiency (PTI), farm flexibility and diseconomies of scope due to the use lagged variables in the TFP determinants' model and the estimation of the PTI model using a between estimator (with one single observation for each sample farm). As farm flexibility and its components were measured for farms with theoretically consistent estimations of production technology, corresponding models show lower numbers of observations as in the IDF model.

21. Tobit model was employed considering that TFP growth rates $(TFP_{i,t}/TFP_{i,t-1})$ are censored at zero.

22. As the analysis is performed for crop farms, in general subsidies measured per hectares of agricultural land should be a good indicator of the extent of subsidisation and allow consistent comparisons across study farms. However, given that subsidies should not show much variation across farms of the same region in Czech, Hungarian and Polish agriculture, as well as in Germany and the UK in recent years (since SAP and SP are determined using regional references for these countries), the use of subsidies measured per unit of land may show some limitations in explaining variation in TFP growth. Accordingly, to validate results of this model, an additional model specification employing subsidies measured per farm output was estimated.

23. Except the Czech sample farms, for which the share of rented land negatively influences productivity growth suggesting potential principal-agent problems on the market for rented land.

24. The squared farmer's age variable was also considered to be used in the model. However, it either was estimated to be not statistically significant or had to be excluded from the model as it showed a high correlation with other model variables.

25. A large share of farms in these countries has an organisational form other than individual farm. Corporate and partnership farms have several owners/partners, tend to be larger and frequently rent land in from the farm partners as well as from other land owners. In France, the partnership form is often acquired by individual farms with several family members owning a part of the farm land. According to the French inheritance legislation, each child receives an equal amount of land (Ciaian et al., 2012).

can be anticipated that corporate farms and partnerships might show higher growth rates than individual farms in France, East Germany and Hungary, for which the rented land share variable obtained a significantly positive parameter estimate. This outcome can be also anticipated considering that a group of shareholders may possess more assets, be less risk averse and have better access to finance than an individual farmer (Binswanger and Rosenzweig, 1986).

Farm investments lagged one and two periods back obtained significant positive estimates for the French and Polish 2004-2013 samples only. Notably, the effect of both investment intensity variables on farm productivity growth was estimated to be significantly negative for English sample farms for the first period. These estimation results suggest that investment of English crop farms might be associated with high capital adjustment costs which may negatively affect farm productivity in initial years of investment implementation.[26] Contract use was found to influence TFP growth differently in West Germany, England and Poland, for which significant estimates were obtained for this variable. Apparently, use of contract services did not pay its costs for West German and Polish sample farms. However, the coefficient estimate for the contract services variable was found to be significantly positive for the English 1995-2003 sample. These results suggest that access to innovative technologies through the use of contract work may depend on the efficiency and transparency of the contract services market organisation. A more competitive and transparent system of contract services could reduce farm costs of accessing innovative technologies and thereby improve productivity of the sector.

Current technologies appear to promote a stronger specialisation in EU crop farming systems. A higher level of crop production diversification was estimated to have a significantly negative influence on farm productivity growth for practically all West European country samples except the English 2004-13 sample suggesting that farms with a higher degree of specialisation tend to have higher TFP growth. This effect was not found to be significant for East European study countries though. A diversification of production towards livestock output was found to improve significantly productivity of French and West German sample farms in both analysed periods. However, while being significantly positive according to the 1995-2003 period estimates, the sign of the livestock share variable turned to be significantly negative for the 2004-2013 English farm sample. Similar trends were observed with respect to the farm involvement in other than crop and livestock production activities for the three analysed West European countries. These findings suggest that economies of scale are pronounced mainly in crop production and that diversification of production to activities other than crop production can positively influence productivity of crop farms in France and Germany. However, livestock production and other agriculture related activities appear to show significantly lower cost efficiency than crop activities and therefore have negatively influenced productivity growth of English sample farms in 2004-13. Diversification towards livestock and other activities was estimated to have a significant positive impact on TFP growth of Czech sample farms. The effect of a higher livestock share in the farm total output was found to be significantly negative for Hungarian farms. A higher share of energy crops appears not to influence farm productivity in any of the analysed countries significantly according to the estimates obtained. Organic farms tend to show a significantly lower productivity growth than conventional farms in France, West Germany and the Czech Republic.

26. An alternative specification of the model for the English 1995-2003 sample incorporating the investment intensity variable with two and three lags back was estimated. While the effect of the investment variable with two lags became insignificant in this model specification, the three-periods-lagged variable obtained a significantly positive coefficient estimate (although at the 10% significance only).

**Table 4. Determinants of TFP change: RE Tobit model estimates, specification with subsidies per hectare of UAA, 1995-2003 and 2004-13**

| Variables | France, 1995-2003 | Germany, 1995-2003 | England, 1995-2003 | France, 2004-2013 | Germany, 2004-2013 | | England, 2004-2013 | Czech Republic, 2004-2013 | Hungary, 2004-2013 | Poland, 2004-2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | West Germany | East Germany | | | | |
| Farm size, hectares of UAA | 0.0007 *** | 0.0020 *** | 0.0006 *** | 0.0004 *** | 0.0022 *** | 0.0001 *** | 0.0003 *** | 0.0001 *** | -0.0001 *** | 0.0003 *** |
| Total subsidies per hectare of UAA | -0.00002 | -0.00003 * | 0.00003 | -0.0001 *** | 0.00001 | -0.0001 *** | -0.00003 | -0.0001 *** | -0.0001 ** | -0.00003 *** |
| Farmer's age | 0.0003 *** | 0.0006 ** | -0.0001 | 0.0003 | 0.0007 *** | 0.0005 | 0.0005 | -0.0001 | 0.0014 ** | 0.0004 |
| Farm organisational form[1)] | -- | 0.03510 *** | -0.01167 | -- | 0.0021 | -- | -0.0017 | -- | -- | -- |
| Paid AWU share | -0.00002 | -0.0001 | 0.0002 ** | 0.00003 | 0.0003 *** | 0.0002 *** | 0.0002 ** | -0.0001 | 0.0008 *** | 0.0004 ** |
| Rented land share | 0.0003 *** | 0.0000 | 0.0000 | 0.0004 *** | 0.0003 *** | 0.0003 * | 0.0004 *** | -0.0003 *** | 0.0011 *** | 0.0015 *** |
| Investment intensity, lag 1 | 0.000000 | 0.000001 | -0.000012 *** | 0.000004 ** | 0.000001 | 0.000002 | 0.00000001 | 0.000003 | -0.00002 | 0.00001 *** |
| Investment intensity, lag 2 | 0.000001 | 0.000002 | -0.000006 * | 0.000004 ** | 0.000002 | -0.000002 | -0.0000003 | 0.000005 | 0.000003 | 0.00001 *** |
| Contract use share | 0.00004 | -0.0012 ** | 0.0014 *** | -0.00005 | -0.0008 ** | -0.0004 | 0.0004 | 0.0004 | -0.0009 | -0.0016 *** |
| Crop production diversification index | -0.0017 * | -0.0038 *** | -0.0046 *** | -0.0020 ** | -0.0042 *** | -0.0020 ** | -0.0014 | -0.0005 | 0.0001 | -0.0018 |
| Livestock output share | 0.0003 *** | 0.0008 *** | 0.0017 *** | 0.0005 *** | 0.0021 *** | -0.0001 | -0.0012 *** | 0.0003 *** | -0.2279 *** | -0.0001 |
| Other farm output share | 0.0006 *** | 0.0005 ** | 0.0028 *** | -0.0003 | 0.0015 *** | 0.0001 | -0.0008 ** | 0.0006 *** | 0.0941 * | -0.0008 |
| Energy crops' area share | -- | -- | -- | -0.0001 | 0.0001 | -0.0002 | 0.0001 | -0.0001 | -0.0001 | -0.0005 |
| Organic farm | -- | -- | -- | -0.0206 *** | -0.0546 ** | -0.0035 | -0.0009 | -0.0116 ** | 0.0336 | -0.0155 |
| LFA | -0.01162 *** | 0.0051 | -0.0407 | -0.0237 *** | -0.0350 *** | -0.0072 | -0.0690 | 0.0035 | 0.0103 | -0.0087 |
| year 1998 | -0.0064 | -0.0017 | -0.0107 | -- | -- | -- | -- | -- | -- | -- |
| year 1999 | -0.018323 * | -0.012442 | 0.015774 * | -- | -- | -- | -- | -- | -- | -- |
| year 2000 | -0.009485 | 0.024462 | 0.016033 | -- | -- | -- | -- | -- | -- | -- |
| year 2001 | 0.01295 *** | 0.0587 *** | 0.0060 | -- | -- | -- | -- | -- | -- | -- |
| year 2002 | 0.0111 *** | -0.0870 *** | 0.0119 | -- | -- | -- | -- | -- | -- | -- |
| year 2003 | 0.0152 *** | -0.0744 *** | 0.0041 | -- | -- | -- | -- | -- | -- | -- |
| year 2007 | -- | -- | -- | 0.0100 *** | -0.0385 *** | -0.0446 *** | 0.0038 | -0.0004 | -0.1091 *** | -0.0183 *** |
| year 2008 | -- | -- | -- | 0.0236 *** | -0.0551 *** | -0.0229 *** | -0.0112 ** | 0.0181 *** | 0.0291 *** | -0.0077 * |
| year 2009 | -- | -- | -- | 0.0466 *** | -0.0067 * | -0.0131 *** | 0.0210 *** | 0.0268 *** | -0.0157 | -0.0217 *** |
| year 2010 | -- | -- | -- | 0.0670 *** | -0.0071 * | -0.0252 *** | 0.0729 *** | 0.0468 *** | 0.0050 | 0.0243 *** |
| year 2011 | -- | -- | -- | 0.0658 *** | -0.0762 *** | -0.0798 *** | 0.0643 *** | 0.0343 *** | 0.0051 | -0.0512 *** |
| year 2012 | -- | -- | -- | 0.0898 *** | -0.0774 *** | -0.0595 *** | 0.0921 *** | 0.0435 *** | -0.0632 *** | -0.0324 *** |
| year 2013 | -- | -- | -- | 0.0778 *** | -0.0767 *** | -0.0721 *** | 0.0739 *** | 0.0492 *** | -0.0176 | -0.0354 *** |
| Bassin parisien | -0.0064 | -- | -- | -0.0006 | -- | -- | -- | -- | -- | -- |
| Nord-Pas-de-Calais | -0.0183 * | -- | -- | -0.0481 *** | -- | -- | -- | -- | -- | -- |
| Est | -0.0095 | -- | -- | -0.0061 | -- | -- | -- | -- | -- | -- |
| Reference region: Île de France | 0.8519 *** | -- | -- | 0.8678 *** | -- | -- | -- | -- | -- | -- |

**Table 4. Determinants of TFP change: RE Tobit model estimates, specification with subsidies per hectare of UAA, 1995-2003 and 2004-13 (*cont'd*)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bayern | -- | -0.0017 | -- | -- | 0.0004 | -- | -- | -- | -- | -- |
| Hessen | -- | -0.0124 | -- | -- | -0.0214 | -- | -- | -- | -- | -- |
| Niedersachsen | -- | 0.0245 | -- | -- | 0.0575 *** | -- | -- | -- | -- | -- |
| Nordrhein-Westfalen | -- | 0.0587 *** | -- | -- | 0.0510 *** | -- | -- | -- | -- | -- |
| Rheinland-Pfalz | -- | -0.0870 *** | -- | -- | -0.0403 *** | -- | -- | -- | -- | -- |
| Saarland | -- | -0.0744 *** | -- | -- | -0.0824 *** | -- | -- | -- | -- | -- |
| Schleswig-Holstein | -- | 0.0291 * | -- | -- | 0.0576 *** | -- | -- | -- | -- | -- |
| Reference region: Baden-Württemberg | -- | 0.7791 *** | -- | -- | 0.7318 *** | -- | -- | -- | -- | -- |
| Mecklenburg-Vorpommern | -- | -- | -- | -- | -- | 0.0619 *** | -- | -- | -- | -- |
| Sachsen | -- | -- | -- | -- | -- | 0.0066 | -- | -- | -- | -- |
| Sachsen-Anhalt | -- | -- | -- | -- | -- | 0.0281 * | -- | -- | -- | -- |
| Thüringen | -- | -- | -- | -- | -- | -0.0025 | -- | -- | -- | -- |
| Reference region: Brandenburg | -- | -- | -- | -- | -- | 0.9466 *** | -- | -- | -- | -- |
| North West (England) | -- | -- | -0.0107 | -- | -- | -- | 0.0137 | -- | -- | -- |
| Yorkshire And The Humber | -- | -- | 0.0158 * | -- | -- | -- | 0.0265 | -- | -- | -- |
| East Midlands (England) | -- | -- | 0.0160 | -- | -- | -- | -0.0068 | -- | -- | -- |
| West Midlands (England) | -- | -- | 0.0060 | -- | -- | -- | 0.0239 | -- | -- | -- |
| East of England | -- | -- | 0.0119 | -- | -- | -- | 0.0179 | -- | -- | -- |
| South East (England) | -- | -- | 0.0041 | -- | -- | -- | 0.0077 | -- | -- | -- |
| South West (England) | -- | -- | -0.0237 ** | -- | -- | -- | 0.0018 | -- | -- | -- |
| Reference region: North East (England) | -- | -- | 0.7927 *** | -- | -- | -- | 0.9146 *** | -- | -- | -- |
| Jihozápad | -- | -- | -- | -- | -- | -- | -- | -0.0056 | -- | -- |
| Severozápad | -- | -- | -- | -- | -- | -- | -- | -0.0121 ** | -- | -- |
| Severovýchod | -- | -- | -- | -- | -- | -- | -- | -0.0093 * | -- | -- |
| Jihovýchod | -- | -- | -- | -- | -- | -- | -- | 0.0031 | -- | -- |
| Střední Morava | -- | -- | -- | -- | -- | -- | -- | 0.0095 * | -- | -- |
| Reference region: Praha | -- | -- | -- | -- | -- | -- | -- | 0.9344 *** | -- | -- |

**Table 4. Determinants of TFP change: RE Tobit model estimates, specification with subsidies per hectare of UAA, 1995-2003 and 2004-13 (*cont'd*)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Közép-Dunántúl | -- | -- | -- | -- | -- | -- | -- | -- | 0.0249 | -- |
| Nyugat-Dunántúl | -- | -- | -- | -- | -- | -- | -- | -- | 0.0389 | -- |
| Dél-Dunántúl | -- | -- | -- | -- | -- | -- | -- | -- | 0.0076 | -- |
| Észak-Magyarország | -- | -- | -- | -- | -- | -- | -- | -- | 0.0074 | -- |
| Észak-Alföld | -- | -- | -- | -- | -- | -- | -- | -- | 0.0017 | -- |
| Dél-Alföld | -- | -- | -- | -- | -- | -- | -- | -- | -0.0006 | -- |
| Reference region: Közép-Magyarország | -- | -- | -- | -- | -- | -- | -- | -- | 0.9316 *** | -- |
| Region Południowy | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1095 *** |
| Region Wschodni | -- | -- | -- | -- | -- | -- | -- | -- | -- | -0.0431 * |
| Region Północno-Zachodni | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1671 *** |
| Region Południowo-Zachodni | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1267 *** |
| Region Północny | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.2086 *** |
| Reference region: Centralny | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.8871 *** |
| sigma u | 0.0627 *** | 0.0963 *** | 0.0668 *** | 0.0690 *** | 0.1069 *** | 0.1233 *** | 0.0868 *** | 0.0254 *** | 0.1129 *** | 0.2100 *** |
| sigma e | 0.0322 *** | 0.0424 *** | 0.0503 *** | 0.0342 *** | 0.0530 *** | 0.0517 *** | 0.0446 *** | 0.0364 *** | 0.1201 *** | 0.0727 *** |
| Number of observations | 4596 | 3031 | 1709 | 4823 | 4555 | 3232 | 1407 | 2084 | 2812 | 5695 |
| Log likelihood | 7912.2 | 4193.9 | 2257.2 | 8092.8 | 5573.3 | 3925.1 | 1950.1 | 3697.6 | 1523.2 | 4801.4 |
| LR test: sigma u=0 | 3831.6 | 2716.0 | 672.0 | 4463.0 | 3907.1 | 3496.5 | 1192.6 | 301.6 | 772.2 | 6844.0 |

*Note*: 1) Farm organisational form was removed for France, East Germany, Czech Republic, Hungary and Poland to avoid multicollinearity due to high correlation with the share of rented land variable.

***, ** and * - statistically significant at the 1, 5 and 10 percentage level, respectively.

### *4.4. Persistent technical inefficiency*

Both components of technical efficiency – transient and persistent efficiencies – were found to be highly statistically significant in most cases. The exceptions were transient technical efficiency for French sample farms for both periods and West German sample farms for the first period. The estimates of the sample average scores of overall technical efficiency and its persistent and transients parts are presented in Table 5. The overall technical efficiency estimates indicate that, as evaluated at the sample averages, sample farms can reduce their costs from 6% up to 27% subject to the study country, to produce the same volumes of outputs. With the average sample score of 0.86, technical efficiency was found to be the lowest among the three West European study countries for the 1995-2003 English sample. For the second period, the lowest sample average overall technical efficiency was estimated for East German sample farms. Among the three East European study countries, the lowest average estimate of overall technical efficiency was found for Hungarian sample farms.

Estimates of the persistent part of technical efficiency appear to exhibit much higher variation in each sample compared to transient technical efficiency. This implies that many sample farms systematically fail to catch up best practices and thus show considerable resource losses compared to farms determining frontier technologies. Transient technical efficiency was found to be lower than the persistent one only for East German and Hungarian sample farms. For Hungary, transient technical efficiency also shows a substantial variation over single years of the analysis. This finding suggests that Hungarian farms input use is not well adjusted to variations in weather and that efforts are required to increase Hungarian crop farms efficiency given country climatic conditions.

Table 6 summarises estimates of the stochastic frontier (SF) model with heteroscedastic technical efficiency and stochastic error terms[27] estimated analogue to a between estimator[28] to explain variation in the persistent part of farm technical inefficiency. The estimates for sample farms for West European countries for both periods indicate that larger farms in these countries tend to show higher persistent technical inefficiencies. However, this result does not apply for the East European and East German samples, for which large farms do not show significantly higher persistent inefficiencies compared to their smaller counterparts. These results suggest that transaction costs which may increase with farm size cause significant input use inefficiencies and cannot be eliminated easily over time in West European farms. Significantly negative estimates of the average marginal effect of the binary variable for farm organisational form (with the value of 1 corresponding to an organisational form other than individual farm) for West Germany and England support this assumption.[29] Farm structures and organisation in East Germany and the three East European study countries appear to be better suited to cope with high transaction costs related to managing large-scale operations. However, sample farms for France and England having higher shares of rented land tend to be more efficient. This may imply that renting land presents an efficient strategy to increase farm size in these countries. Given that farms renting land have to pay land rent, they also might be more aware about land input opportunity costs. For the Czech sample, the rented land share variable was estimated to have a significantly positive average marginal effect on persistent technical inefficiency. Considering that this variable showed a negative effect also on TFP growth for Czech farms, it appears that Czech farms have to deal with high transaction costs in the land rental market. Ciaian et al. (2012) refer to information asymmetries as a source of

27. This stochastic frontier model formulation is applied to farm random effects estimated according to the procedure described in section “Estimation procedure” in Annex A and assumes that variances of the both error terms are functions of a set of variables. The approach proposed by Wang was employed to derive average marginal effects of variables used to explain heteroscedasticity on unconditional expected values of persistent technical inefficiency (Wang, 2002).

28. That means to explain variations across farms exclusively. Accordingly, the estimations are done employing the period average values of variables.

29. The effect of farm organisational form was studied for 2004-13 only, as there were only few observations on non-individual farms for the 1995-2003 period. For France, this variable was removed as it showed high correlation with the rented land variable in the 2004-13 sample.

high transaction costs in the Czech land rental market. Disputes about the magnitude of land rents and uncertainty about property rights may aggravate farm decision-making and distract farm operators from pursuing other managerial tasks and in this way affect farm efficiency.

Farms with higher investment intensity were found to be more technically efficient for the East German, Czech and Polish samples. This finding may imply that the effect of investment were used largely to reduce the gap to frontier technologies on average in the 2004-13 period rather than to shift frontier technologies and is in line with the technical change estimates for these three study countries. Contract use share was estimated to reduce significantly farm persistent technical inefficiency for the West German Hungarian and Polish farm samples in 2004-13. However, West German 1995-2003 sample farms and Czech 2004-13 sample farms were found to have higher inefficiencies when increasing the share of contract services cost in total costs. Contract services may be an important channel of technology spillovers and learning effects and thus positively influence technical efficiency and productivity. However, they have to be cost efficient and delivered timely to enhance farm productivity and technical efficiency.

Crop farms engaged in livestock and agriculture-related activities can be anticipated to have higher scores of technical efficiency according to the estimates obtained for French, East German, Czech and Hungarian sample farms. This can be related to a more efficient use of labour on individual farms and farms with regular paid labour. Diversification of production within crop production was estimated to worsen farm persistent inefficiency mainly. Organic farms and farms situated in Less Favoured Areas (LFA) also tend to overuse persistently resources compared to best practice farms.

**Table 5. Sample average technical efficiency estimates**

France, Germany and England, 1995-2003 and 2004-13

| | France | | | | Germany | | | | | | England | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | West Germany | | | | East Germany | | | | | |
| | 1995-2003 | | 2004-2013 | | 1995-2003 | | 2004-2013 | | 2004-2013 | | 1995-2003 | | 2004-2013 | |
| | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. |
| Overall technical efficiency | 0.92 | 0.05 | 0.94 | 0.05 | 0.94 | 0.05 | 0.89 | 0.07 | 0.86 | 0.07 | 0.85 | 0.07 | 0.89 | 0.05 |
| Persistent technical efficiency | 0.92 | 0.05 | 0.94 | 0.05 | 0.94 | 0.05 | 0.92 | 0.07 | 0.94 | 0.07 | 0.92 | 0.06 | 0.95 | 0.05 |
| Transient technical efficiency | not significant | | not significant | | not significant | | 0.96 | 0.01 | 0.92 | 0.03 | 0.92 | 0.03 | 0.94 | 0.02 |

Czech Republic, Hungary and Poland, 2004-13

| | Czech Republic | | Hungary | | Poland | |
|---|---|---|---|---|---|---|
| | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. |
| Overall technical efficiency | 0.85 | 0.06 | 0.73 | 0.11 | 0.88 | 0.05 |
| Persistent technical efficiency | 0.93 | 0.05 | 0.89 | 0.08 | 0.94 | 0.04 |
| Transient technical efficiency | 0.91 | 0.04 | 0.83 | 0.09 | 0.94 | 0.02 |

*Note:* the technical efficiency value of 1 means that the farm is technically efficient, while a value of technical efficiency less than 1 for a farm indicates that it overuses resources compared to best practices farms with technical efficiency values of 1.

Finally, support provided to farms in form of subsidies was found to preserve persistent technical inefficiency for most countries according to the results obtained in this report. By lessening the effect of competitive forces, producer support can reduce farmers' incentives to catch up and allow inefficient and loss-making farms to stay in business. The magnitude of the average marginal effect of subsidies was found to be highest for the East German, English and Hungarian 2004-13 samples. The effect was estimated to be not significant for Czech sample farms. For the French 2004-13 sample, subsidies measured per hectares of land were estimated to reduce persistent technical inefficiency. This result implies that subsidies were reducing the variance in technical inefficiency across farms in France in recent years. This may be due to a positive effect of subsidies on farm budget constraints and thus access to finance required for technology upgrading. However, subsidies as measured per farm total output were estimated to have a significantly negative effect on farm persistent technical efficiency for all country samples (Annex Table B.5). The difference in the effect of subsidies measured per hectares of land and 1 Euro of farm output is due to the fact that subsidies per hectare do not account for differences in farm land productivity/quality, while this effect is incorporated in the subsidies to farm output ratio.

An interesting result comes out when estimating the stochastic frontier model with heteroscedastic persistent technical inefficiency distinguishing between coupled and decoupled payments (Annex Table B.6). The model estimation results indicate that decoupled payments per hectare of UAA do not show any significant effect on farm persistent technical inefficiency for most countries. For farms from the Hungarian sample they were measured even to reduce persistent technical inefficiency significantly.

### *4.5. Allocative inefficiencies*

The analysis of allocative inefficiencies was done at the meta-level to evaluate deviations of farm shadow prices from market prices which have a systemic character. Table 7 presents the estimates of sample average marginal products (MP) and prices for single factors of production. These estimates indicate that crop farms in the study countries tend to use their production factors sub-optimally. Land appears to be underused in most study countries given its rental prices. The only exceptions are the English 2004-13 sample farms, which as evaluated at the sample averages do not show any considerable deviations between the land MP and land rents, and East German sample farms, which tend to overuse land. Differences between land marginal pricing and rents may be related to regulations used in single countries to control land rent. Also high transaction costs on land markets may explain the presence of allocative inefficiencies in land use.

French farms appear to be allocatively efficient in their labour use - for both periods of the analysis agricultural worker wages were found to be very close to labour MPs as evaluated at the sample averages for France. East German, English and Czech sample farms were revealed to overuse labour given agricultural worker wages. This might be due to labour market regulations, but also due to surplus labour in case of capital-biased technical change. West German, Hungarian and Polish sample farms appear to underuse labour considering the magnitude of agricultural worker wages in these country samples, respectively. These findings may indicate low flexibility of farms in releasing excessive labour or engaging additional workers for a short period due to current employment regulations. Notably, the analysis reveals substantial differences in marginal productivity of labour and its remuneration between East German and West German sample farms. These are potentially due to different wage structures – while paid labour on West German crop farms consists of seasonal workers mainly, paid agricultural workers in East German farms are often employed on a regular basis.

Capital input shows strong divergences from its optimal allocation given its market prices. West German and English sample farms were estimated to have lowest marginal products of capital – one additional Euro spent on capital input generates only EUR 0.51 and EUR 0.53, respectively, as estimated at the sample averages. MP of capital is also rather low for French sample farms. East German, Czech and Polish sample farms appear to have similar magnitudes of capital MPs. A value of the capital MP above EUR 1 for Hungarian farms implies that they underuse capital and can improve their economic performance by increasing capital use. In general, farms may overuse capital and other factors in the presence of risk and risk aversion. Additionally, farm fixed assets price may not adequately express capital opportunity costs. Empirical evidence also shows that farms tend to acquire machines and equipment with capacities larger than required in production. Lumpiness of most capital items and technical progress favouring large scale production may amplify this phenomenon. Two potential options for improving capital allocation are: first, facilitating transparent and efficient markets for agricultural machinery and contract services, including collective use of machines in agricultural machinery cooperatives and exchange of services between farmers; second, promoting the development of scalable and flexible technologies and equipment which can be easily adjusted to specifics and requirements of different crops. Both options could encourage farms also to explore advantages of economies of scope.

**Table 6. Average marginal effects of selected factors on unconditional expected value of persistent technical inefficiency: Estimates of SF model with heteroscedasticity, specification with subsidies per hectare of UAA**

France, Germany and England, 1995-2003[1)]

| Variable | France | West Germany | England |
|---|---|---|---|
| Farm size, hectares of UAA | 0.0003 *** | 0.0005 *** | 0.0001 * |
| Total subsidies per hectare of UAA | 0.0001 | 0.0002 *** | 0.0001 * |
| Farmer's age | -0.0007 | -0.0013 ** | -0.0039 |
| Paid AWU share | 0.0002 | -0.0002 | 0.0002 |
| Rented land share | -0.0001 | -0.0001 | -0.0001 |
| Investment intensity | -0.0001 | -0.00004 | 0.0000 |
| Contract use share | 0.0002 | 0.0019 ** | -0.0002 |
| Crop production diversification index | 0.0009 | 0.0025 | 0.0109 *** |
| Livestock output share | 0.0001 | 0.0001 | -0.0001 |
| Other farm output share | -0.0012 | -0.0006 | -0.0011 |
| LFA | 0.0466 *** | 0.0516 *** | -0.0335 |
| Bassin parisien | -0.0645 *** | -- | -- |
| Nord-Pas-de-Calais | -0.0983 *** | -- | -- |
| Est | -0.0742 *** | -- | -- |
| Reference region: Île de France | -- | -- | -- |
| Bayern | -- | 0.0222 | -- |
| Hessen | -- | 0.0368 | -- |
| Niedersachsen | -- | 0.0521 ** | -- |
| Nordrhein-Westfalen | -- | 0.0080 | -- |
| Rheinland-Pfalz | -- | 0.0152 | -- |
| Saarland | -- | 0.0007 | -- |
| Schleswig-Holstein | -- | 0.0042 | -- |
| Reference region: Baden-Württemberg | -- | -- | -- |
| North West (England) | -- | -- | 0.0320 |
| Yorkshire And The Humber | -- | -- | -0.1657 |
| East Midlands (England) | -- | -- | -0.0309 |
| West Midlands (England) | -- | -- | -0.0018 |
| East of England | -- | -- | -0.0059 |
| South East (England) | -- | -- | 0.0387 ** |
| South West (England) | -- | -- | 0.0040 |
| Reference region: North East (England) | -- | -- | -- |
| Number of observations | 1 036 | 732 | 421 |
| Likelihood ratio test ($H_0$: $\sigma_u = 0$) | 175.5 *** | 178.8 *** | 97.2 *** |

France, Germany and England, 2004-13

| Variable | France | Germany | | England |
|---|---|---|---|---|
| | | West Germany | East Germany | |
| Farm size, hectares of UAA | 0.0002 *** | 0.0005 *** | 0.00001 | 0.0001 * |
| Total subsidies per hectare of UAA | -0.0001 ** | 0.0001 *** | 0.0002 *** | 0.0002 *** |
| Farmer's age | 0.00001 | -0.0010 *** | -0.0001 | -0.0018 |
| Farm organisational form[2)] | -- | 0.0420 ** | -- | 0.0510 * |
| Paid AWU share | 0.0005 *** | -0.00001 | 0.0003 | -0.0001 |
| Rented land share | -0.0003 * | 0.0002 | 0.0002 | -0.0004 ** |
| Investment intensity | -0.00005 | 0.00001 | -0.0002 *** | -0.0001 |
| Contract use share | -0.00005 | -0.0017 * | -0.0010 | 0.0002 |
| Crop production diversification index | 0.0049 * | 0.0137 *** | -0.0022 | 0.0056 |
| Livestock output share | -0.0009 ** | -0.0003 | -0.0004 * | 0.0000 |
| Other farm output share | -0.0041 *** | -0.0006 | 0.0003 | -0.0007 |
| Organic farm | 0.1208 * | -0.0042 | -0.0083 | -0.0137 |
| LFA | 0.0328 *** | 0.0409 *** | 0.1047 *** | 0.0025 |
| Bassin parisien | 0.0102 | -- | -- | -- |
| Nord-Pas-de-Calais | -0.0327 | -- | -- | -- |
| Est | -0.0057 | -- | -- | -- |
| Reference region: Île de France | -- | -- | -- | -- |
| Bayern | -- | -0.0120 | -- | -- |
| Hessen | -- | -0.0301 * | -- | -- |
| Niedersachsen | -- | 0.0252 * | -- | -- |
| Nordrhein-Westfalen | -- | -0.1471 *** | -- | -- |
| Rheinland-Pfalz | -- | 0.0061 | -- | -- |
| Saarland | -- | 0.0503 *** | -- | -- |
| Schleswig-Holstein | -- | -0.0450 ** | -- | -- |
| Reference region: Baden-Württemberg | -- | -- | -- | -- |
| Mecklenburg-Vorpommern | -- | -- | -0.0006 | -- |
| Sachsen | -- | -- | -0.0099 | -- |
| Sachsen-Anhalt | -- | -- | -0.0063 | -- |
| Thüringen | -- | -- | -0.0339 *** | -- |
| Reference region: Brandenburg | -- | -- | -- | -- |
| North West (England) | -- | -- | -- | 0.0038 |
| Yorkshire And The Humber | -- | -- | -- | -0.0382 |
| East Midlands (England) | -- | -- | -- | -0.0256 |
| West Midlands (England) | -- | -- | -- | -0.0406 |
| East of England | -- | -- | -- | -0.0294 |
| South East (England) | -- | -- | -- | -0.0026 |
| South West (England) | -- | -- | -- | -0.0209 |
| Reference region: North East (England) | -- | -- | -- | -- |
| Number of observations | 896 | 931 | 651 | 308 |
| Likelihood ratio test ($H_0$: $\sigma_u = 0$) | 207.7 *** | 343.5 *** | 182.4 *** | 82.9 *** |

Czech Republic, Hungary and Poland, 2004-13

| Variable | Czech Republic | Hungary | Poland |
|---|---|---|---|
| Farm size, hectares of UAA | 0.00001 | -0.00003 * | 0.00001 |
| Total subsidies per hectares of UAA | 0.0001 | 0.0002 ** | 0.0001 *** |
| Farmer's age | -0.0019 ** | 0.0003 | -0.0016 *** |
| Farm organisational form[2)] | -- | -- | -- |
| Paid AWU share | -0.0007 | 0.0001 | 0.0006 *** |
| Rented land share | 0.0008 * | 0.0001 | 0.0002 |
| Investment intensity | -0.0002 ** | -0.00002 | -0.0001 ** |
| Contract use share | 0.0025 * | -0.0081 *** | -0.0062 *** |
| Crop production diversification index | 0.0086 *** | 0.0051 *** | 0.0019 |
| Livestock output share | -0.0008 ** | -0.0011 *** | 0.0002 |
| Other farm output share | -0.0002 | -0.0020 * | -0.0017 |
| Organic farm | 0.0039 | 0.2154 ** | 0.0711 * |
| LFA | -0.0051 | 0.0365 * | 0.0608 *** |
| Jihozápad | 0.0310 * | -- | -- |
| Severozápad | 0.0302 | -- | -- |
| Severový chod | 0.0293 | -- | -- |
| Jihový chod | -0.0040 | -- | -- |
| Střední Morava | -0.0237 | -- | -- |
| Moravskoslezsko | 0.0051 | -- | -- |
| Reference region: Praha | -- | -- | -- |
| Közép-Dunántúl | -- | -0.0235 | -- |
| Nyugat-Dunántúl | -- | -0.0163 | -- |
| Dél-Dunántúl | -- | 0.0107 | -- |
| Észak-Magyarország | -- | -0.0226 | -- |
| Észak-Alföld | -- | -0.0104 | -- |
| Dél-Alföld | -- | -0.0253 | -- |
| Reference region: Közép-Magyarország | -- | -- | -- |
| Region Południowy | -- | -- | 0.0078 |
| Region Wschodni | -- | -- | -0.0023 |
| Region Północno-Zachodni | -- | -- | -0.0137 |
| Region Południowo-Zachodni | -- | -- | 0.0083 |
| Region Północny | -- | -- | -0.0122 |
| Reference region: Centralny | -- | -- | -- |
| Number of observations | 429 | 538 | 1 119 |
| Likelihood ratio test, H0: $\sigma_u = 0$ | 179.4 *** | 105.3 *** | 192.9 *** |

*Note*: ***, ** and * - statistically significant at the 1, 5 and 10% level, respectively.
1) The farm organisational form and organic farms variables were removed from the 1995-2003 farm samples because only a few observations were available on these variables for this period for between estimations
2) Farm organisational form was removed for France, East Germany, Czech Republic, Hungary and Poland to avoid multicollinearity due to high correlation with the share of rented land variable

Notably, cost efficiency of materials use was estimated to be substantially higher for 2004-13 compared to 1995-2003 for the three West European samples. Although differences in the composition of 1995-2003 and 2004-13 samples limit direct comparisons between these two periods, it can be anticipated that a stricter implementation of cross-compliance regulations since the 2003 decoupling reform may induced farms to apply materials more efficiently. Also policies had a less market distorting character in this period. Given that farms can more easily introduce adjustments in their variable input use than in fixed factors of production, materials use can be also anticipated to show higher responsiveness to changes in policy. However, for West German and Polish farms, materials use still shows substantial allocative inefficiencies. The latter may be related to potentially higher downside risk aversion of small farmers even in the presence of decoupled payments.

**Table 7. Factor prices and marginal products (MP): Sample average estimates by country and period**

| Country/period | Marginal products | | | | Land rent per hectare | Annual wage per AWU |
|---|---|---|---|---|---|---|
| | Materials | Land | Labour | Capital | | |
| **1995-2003 period, Euro of 2000** | | | | | | |
| France | 0.83 | 135 | 16,934 | 0.69 | 41 | 17,942 |
| West Germany | 0.74 | 556 | 22,231 | 0.72 | 375 | 17,245 |
| England | 0.69 | 155 | 15,574 | 0.85 | 193[1)] | 19,772 |
| **2004-2013 period, Euro of 2010** | | | | | | |
| France | 0.87 | 250 | 23,104 | 0.61 | 137 | 20,560 |
| Germany | | | | | | |
| - West Germany | 0.80 | 368 | 23,668 | 0.51 | 241 | 19,076 |
| - East Germany | 0.98 | 106 | 18,514 | 0.79 | 160 | 22,894 |
| England | 0.92 | 251 | 16,974 | 0.53 | 245 | 25,009 |
| Czech Republic | 0.93 | 118 | 7,651 | 0.78 | 54 | 10,846 |
| Hungary | 0.90 | 182 | 8,646 | 1.71 | 90 | 6,680 |
| Poland | 0.79 | 182 | 7,138 | 0.81 | 63 | 4,414 |

1. Only a few observations on land rents are available for English sample farms for 1995-2003. Eurostat statistics on land rents for the United Kingdom were used to approximate land rents of English sample farms for 1995-2003.

### *4.6. Farm flexibility and economies of scope*

Table 8 summarises estimates of the flexibility index derived based on the IDF parameter estimates and its three components – the economies of scope effect, scale effect and convexity effect. This part of the analysis was performed for the 2004-13 period exclusively. As already mentioned earlier in the report, lower values of the flexibility index by Cremieux et al. (2005) and its components correspond with higher flexibility. The economies of scope effect can be either negative indicating the presence of cost complementarities in integrated production systems or positive implying diseconomies of scope. The flatter the curvature of the average cost function, the lower the convexity effect, indicating the ability to adjust levels of production to changes in demand at relatively low costs. Low values of the scale effect suggest that farms are saving costs by specialising on production of single outputs.

Flexibility was estimated to be statistically significant for five of the country samples as evaluated at respective country sample averages – the both parts of Germany, England, the Czech Republic and Poland. Among these five countries, Hungarian farms were estimated to use most flexible technologies. English sample farms also were found to show relatively high flexibility.

The economies of scope effect was estimated to be positive for all farm samples implying that technologies used currently by crop farms do not show complementarities in the production of the three analysed farm outputs. However, economies of scope may be present at less aggregated levels, that is between smaller groups of farm outputs than considered in this report.[30] English sample farms were the only group, for

30. The parametric method used sets some restrictions on the number of outputs and inputs used in the model. Economies of scope for more disaggregated outputs/groups of outputs can be studied using non-parametric methods. However, the latter might be less suited to capture stochastic nature of crop production.

which an indication for a significant weak complementarity between two groups of outputs – cereals and other crops – was estimated. Despite this fact, the overall effect of economies of scope was estimated to be positive, however, not significant for English sample farms. Significant estimates of diseconomies of scope were obtained for West and East German, Czech, and Polish sample farms. Among these four country samples, diseconomies of scope were measured to be of the lowest magnitude for West German farms as evaluated at the sample averages. Polish farms appear to show also relatively low diseconomies of scope. Diseconomies of scope were found to be large for Czech and East German sample farms.

The scale effect was computed to be the lowest at the sample average for Czech sample farms, although not significant, and Hungarian sample farms. Among the country samples with significant estimates, highest estimates of the convexity effect were obtained for the Czech and West German samples suggesting smoothest adjustments in farm size for these two country samples.

The results of the analysis performed to explain variation in farm flexibility and (dis)economies of scope (Annex Tables B7 and B8, respectively) for the country samples with significant estimates of both indicators (at respective sample averages) suggest that large crop farms in East Germany, England, Hungary and Poland show higher flexibility.[31] In line with the results discussed earlier, this finding suggests that highly specialised large-scale operations appear to have cost advantages compared to more diversified crop production systems in these countries. For West Germany a negative and significant relationship between farm flexibility and farm size was estimated implying that farms in West Germany may exploit other sources of cost flexibility than farms in East German and other study countries. They show relatively low diseconomies of scope and a flatter curvature of the average cost function (Table 8).

**Table 8. Flexibility and its components: sample average estimates by country, 2004-13[1]**

| | Flexibility | | Economies of scope effect | | Scale effect | | Convexity effect | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| France (N = 3 762) | 0.082 | 0.284 | 0.160 | 0.209 | 0.342 | 0.233 | -0.419 | 0.273 |
| West Germany (N = 3 978) | 0.351 | 0.065 | 0.111 | 0.081 | 0.566 | 0.079 | -0.326 | 0.095 |
| East Germany (N = 882) | 0.405 | 0.169 | 0.336 | 0.045 | 0.334 | 0.124 | -0.264 | 0.084 |
| England (N = 1 279) | 0.299 | 0.070 | 0.060 | 0.078 | 0.360 | 0.101 | -0.122 | 0.094 |
| Czech Republic (N = 575) | 0.044 | 0.045 | 0.350 | 0.122 | 0.043 | 0.074 | -0.349 | 0.112 |
| Hungary (N = 2 461) | 0.169 | 0.074 | 0.505 | 1.592 | 0.242 | 0.113 | -0.579 | 1.604 |
| Poland (N = 5 711) | 0.577 | 0.167 | 0.218 | 0.085 | 0.666 | 0.203 | -0.306 | 0.050 |

1. Since flexibility refers to marginal increases in average cost per unit of output, the lower the value of the flexibility index and its components the higher is the flexibility. Flexibility and its components were estimated only for the sample farms, for which theoretically consistent results were obtained with respect to all inputs and outputs.

West German farms with higher flexibility are more diversified, rely stronger on contract work and paid labour, have significantly higher crop area shares of proteins and energy crops, but also use more intensive production practices (as signalled by the significantly negative sign of the fertilizer and plant protection variable). Flexibility was increasing significantly over the 2004-13 in West German sample farms.

Higher flexibility is found to correlate significantly with the following characteristics of East German farms – higher share of paid labour and contract work, stronger diversification towards activities beyond crop production, lower intensity of chemical fertilizer and plant protection use. No significant differences were found for East German sample farm flexibility across regions and over time.

31. Both models were estimated as fixed and random effects' models; subsequently Hausman test was performed to compare estimates of those models. According to this text, the random effects model was preferred for all analysed samples.

Contrary to the findings for German crop farms, English sample farms estimated to have higher flexibility use significantly less contract work than those found to show lower flexibility. Flexible farms in the English sample appear to have significantly higher paid labour and rented land shares, relatively low magnitudes of diversification in crop production but higher shares of livestock output. Similar to West German sample farms, they also tend to use more mineral fertilizer and plant protection materials. The estimates of the model also indicate that farm flexibility was decreasing in England since 2007.

Hungarian farms can significantly improve their flexibility by involving stronger in crop production diversification and production of farm outputs beyond those from crop and livestock production. Similar to English farms they have higher shares of paid labour and lower shares of contract work costs in total costs. Similar to East German farms with higher flexibility, they tend to have relatively low shares of fertilizer and plant protection costs in total cost.

Polish sample farms assessed to be more flexible show analogue to English sample farms significantly higher shares of paid labour and rented land, higher extent of specialisation within crop production and higher shares of livestock output. They also have lower shares of contract work costs in total costs. Additionally, similar to West German farms which also have relatively small farm structures, Polish farms appear to increase their flexibility through more intensive use of fertilizer and herbicides. The three regions situated in the West and South-West of the country have farm structures exhibiting higher flexibility than farms in the Northern and Eastern Poland. Although farm flexibility was varying over time significantly, it did not show any particular trend.

Decoupled payments were found to encourage East German farms to improve flexibility. For the four other country samples with significant flexibility estimates, the effect of subsidies was not found to be significant. A significant negative rank correlation was measured to be present between TFP growth and flexibility values for East German, English, Hungarian and Polish sample farms implying a positive relationship between these two indicators for these four country samples. No significant correlation was found between farm flexibility and TFP growth for West German sample farms.

Only a few factors were revealed to reduce significantly diseconomies of scope (Annex Table B.8). West German farms with lower diseconomies of scope have higher shares of rented land. They also tend to show a larger extent of diversification in crop production and higher shares of energy crops in arable land. Farms situated in less favoured areas also show lower diseconomies of scope obviously because they cannot be as cost efficient due to intensification as their counterparts located in more productive regions. The estimation results for the Polish farm sample indicate that there is a significant potential to reduce costs in integrated production systems by getting access to specific technologies through contract work provided by farms specialised in relevant activities. For all three country samples with significant estimates of the economies of scope effect, the intensity of chemical fertilizer use and plant protection was found to significantly increase diseconomies of scope. Those results suggest that technologies currently used on farms appear to favour a stronger specialisation and intensification of production.

## 5. Conclusions

This report evaluates total factor productivity of crop farms in the European Union (EU) in the period after the implementation of the 1992 MacSharry and 2003 Decoupling reforms of the EU Common Agricultural Policy. The analysis was performed for six selected EU member states – the Czech Republic, France, Germany, Hungary, Poland and the United Kingdom. Farm Accountancy Data Network data of the European Commission for two periods – 1995-2003 and 2004-13 (based on Standard Gross Margin and Standard Output farm typologies, respectively) – were used to measure and decompose farm TFP growth. TFP growth estimates in this report are based on farm-level data may diverge from sector-level TFP growth estimates.

Crop farm TFP growth was found to show similar magnitudes and patterns during the 1995-2003 period for the three West European countries covered in the report. French and West German sample farms increased their productivity annually at an average rate of 0.7%, while the English sample farms average TFP growth was 0.9% per year. These findings are consistent with USDA productivity estimates at the sector level, which revealed a steady – although moderate – growth in EU agriculture for the period after the implementation of the MacSharry 1992 CAP reform (Ball et al. 2010). Major sources of TFP growth in France and Germany were technical change, which grew, respectively, at a rate of 0.5% and 0.6% annually on average. English crop farms' TFP growth was increasing mainly due to the scale effect in 1995-2003.

The productivity trends for the later 2004-13 period were found to be more diverse. While TFP was estimated to grow for English, French, and Czech sample farms at 1.7%, 1.1% and 0.7%, respectively, it showed a substantial decrease for German and Hungarian sample farms. TFP growth was growing at 0.1% annually as evaluated at the sample average for Polish crop farms. With, on average, 2.4% for English sample farms and 1.3% for French sample farms, technical change was measured to be considerably higher for this period than for 1995-2003 and compared to the other four analysed countries. Though estimated separately, TFP growth rates showed similar trends and magnitudes for West German and East German sample farms. Negative technical change was identified to be the major reason for German farm productivity decline. These results suggest that there were some systemic changes in the German crop farms' external environment which provoked this trend in TFP development. The differences in TFP developments across countries revealed for 2004-13 suggest that country specificities and models of the CAP 2003 reform implementation played an important role in determining crop farm productivity growth.

Technologies currently applied on crop farms show substantial economies of scale and therefore favour large-scale operations. However, although the scale effect contributed considerably to farm TFP growth in single years of the 2004-13 period, its average effect over the whole period was negligible. High agricultural commodity prices since the 2007 price spikes should have encouraged farms to extend scales of production; however, increased price volatilities may have forced farmers to revise their production decisions repeatedly. Access to effective instruments of market risk reduction can ease farm decision-making, extend farm planning horizon, and thereby improve farmers' capacities to benefit from economies to scale.

Large farms were estimated to show higher productivity growth rates in the analysis of TFP drivers. They appear to be in a better position to exploit economies of scale and to invest in productivity-enhancing technologies than small-scale farms. This may explain an increasing gap in TFP growth between farm groups by size, which was revealed for the French and English 2004-13 samples. Farm investments were found to enhance productivity growth for the French and Polish 2004-13 samples. For East German, Czech and Polish sample farms, investment were revealed to help farms to close the gap to frontier technologies. Results obtained for other country samples suggest the presence of high capital adjustment costs which by impeding a proficient investment implementation appear to delay payoffs on farm investment. Training activities such as workshops and farmers' field days can improve farmers' managerial abilities and skills and help to reduce transaction costs related to adoption of new technologies.

Farms can reduce their costs from 6% up to 27%, depending on the country, to produce the same volumes of output as evaluated at the sample averages. Persistent failures to close the gap to frontier technologies were identified to be the major source of farm productive inefficiencies. Farm structures and organisation in East Germany, the Czech Republic and Hungary appear to be better suited to cope with high transaction costs related to managing large-scale operations in crop farming.

Farm support in the form of subsidies is found to negatively influence crop farm productivity growth and efficiency of input use. Farm TFP growth was estimated to be lower and persistent technical inefficiency higher for farms receiving more subsidies. This holds if subsidies are measured as total subsidies per hectare of agricultural land, or alternatively as total subsidies per farm total output, and controlling for farms located in less favoured areas (LFA). Although subsidies may relieve farm budget constraints and in this way improve their access to frontier technologies, they also enable chronically loss-making farms to stay longer in business than would be feasible in a more competitive environment. Decoupled payments are found to be less distorting productivity than coupled payments – they are estimated not to influence farm efficiency significantly for most study countries and reduce farm inefficiencies in input use for the Hungarian sample.

Current technologies appear to promote a stronger specialisation of EU crop farms and promote large-scale operations. This result was supported by finding of an analysis of farm flexibility. Flexibility of crop farms was identified to be determined mainly by the convexity and scale effects under current technologies. The presence of the convexity effect implies that technologies can reduce the effect of resource scarcity and thus make adjustments in size of operations less costly. The scale effect encourages farms to exploit economies of scale and in this way increase their cost efficiency. No significant economies of scope were revealed to be present in crop farms of the analysed countries implying absence of significant cost complementarities between three analysed groups of outputs in the study countries. The only exception was the English sample, for which a significant weak complementarity between cereals and other crops production was measured. For two countries – Germany and Poland – significant diseconomies of scope were estimated at sample averages. Farm flexibility and diseconomies of scope were found to increase with an increasing intensity of fertilizer use and plant protection. This finding is in line with theoretical expectations, with fertilizer and plant protection compensating resource scarcity and allowing to extend production beyond boundaries set by nature.

A meta-level analysis of allocative inefficiencies suggests that allocative inefficiencies with respect to variable inputs use were substantially lower for 2004-13 compared to 1995-2003 for the three West European countries analysed in this report. This development may express a positive effect of decoupling on variable input use in crop farms: decoupled payments have a less distorting character on farm output and factor prices; conditioned on environmental cross-compliance they may motivate farmers to avoid excesses in fertilizer and herbicide use; finally being decoupled from production they may have a mitigating effect on farmers' exposure to downside risk and, therefore, reduce their marginal risk premium.

As evaluated at the meta level, French farms were found to be allocatively efficient in labour use, while English crop farms appear to have optimal size considering English agricultural land rents. For practically all country samples except the Hungarian one, farms were found to overuse capital. Lumpiness of most capital items and technical progress favouring large-scale operations may be an explanation for the existence of capital allocative inefficiencies. Two potential options for improving farm capital allocation are: first, assisting emergence of a vibrant, transparent and efficient market of contract services which can be used by farms to offer and exchange their contract work services, and facilitating collective use of machines in agricultural machinery cooperatives; second, promoting the development of scalable and flexible technologies and equipment which can be easily adjusted to specifics and requirements of different crops.

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# Annex A.

## Description of the methodology

***Input Distance Function***

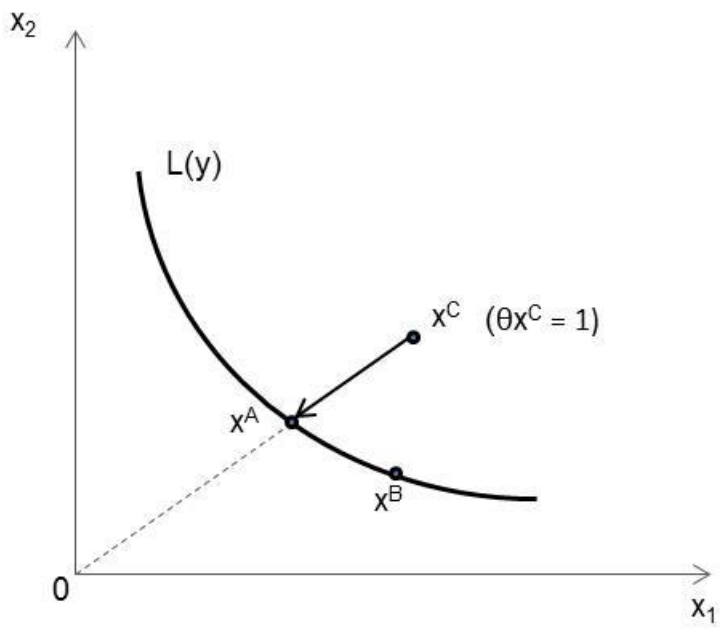
TFP growth is measured and decomposed based on parameter estimates of a stochastic input distance function (IDF) (Karangiannis et al., 2004). An input distance function measures the maximum amount by which input use can be radially reduced but still feasibly produce a given vector of output (Shephard, 1953). The input distance function is a transformation function and is formally defined as:

$$D_I(\boldsymbol{y},\boldsymbol{x},t) = max\left\{\lambda : \left(\frac{x}{\lambda}\right) \in L(\boldsymbol{y})\right\}, \quad (1)$$

where $\boldsymbol{x}$ denotes the input vector, $\boldsymbol{x} \in R_+^K$, **y** stands for the output vector, $\boldsymbol{y} \in R_+^M$, time variable $t$ captures technical change and $L(\boldsymbol{y})$ represents the input isoquant for producing $\boldsymbol{y}$. The input isoquant corresponds to the sets of input vectors that have input distance function equal to one.

The input distance function can be used to derive the input-oriented measure of technical efficiency, $TE(\boldsymbol{y},\boldsymbol{x},t) = min\{\theta : D_I(\boldsymbol{y},\boldsymbol{x}\theta,t) \geq 1\}$, with $\theta = \frac{1}{\lambda}$. Technically efficient firms have input vectors located on the input isoquant, whereas input vectors of technically inefficient firms are beyond the input isoquant. Figure A.1. presents an input distance function of two inputs. Points $x^A$ and $x^B$ represent efficient producers, while point $x^C$ corresponds with technically inefficient producer, for whom $0 < \theta \leq 1$.

**Figure A.1. A graphic representation of an input distance function with two inputs**



The input distance function exhibits the following properties (Färe and Primont, 1995): it is non-decreasing, positively linearly homogenous and concave in inputs, and non-increasing and convex in outputs. In this project, A flexible functional form – the translog function – was used to model the input distance function. Accordingly, the input distance function is defined as follows:

$$lnD_{Iit} = \alpha_0 + \sum_{m=1}^{M} \alpha_m ln\, y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} lny_{mit} lny_{nit} + \sum_{k=1}^{K} \beta_k ln\, x_{kit}$$

$$+\frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} lnx_{kit} lnx_{lit} + \sum_{k=1}^{K}\sum_{m=1}^{M} \gamma_{km} lnx_{kit} lny_{mit}$$

$$+\delta_t t + \frac{1}{2}\delta_{tt} t^2 + \sum_{m=1}^{M} \alpha_{mt} t lny_{mit} + \sum_{k}^{K} \beta_{kt} t ln\, x_{kit} \quad (2)$$

where subscripts $i$, with $i$ =1, 2,…,N, refers to the $i$-th producer and $t$, with $t =1, 2,...,T$, denotes time (year). $\boldsymbol{y}$ is a [Mx1] vector of outputs and $\boldsymbol{x}$ is a [Kx1] vector of inputs. $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$ and $\boldsymbol{\delta}$ are vectors of technology parameters to be estimated.

The input distance function is homogenous of degree 1 in inputs. This requires

$$\sum_{k=1}^{K} \beta_k = 1, \sum_{k=1}^{K} \beta_{kl} = \sum_{k=1}^{K} \beta_{kt} = \sum_{k=1}^{K} \gamma_{km} = 0\,. \quad (3)$$

Symmetry restrictions imply

$$\alpha_{mn} = \alpha_{nm}, \text{ and } \beta_{kl} = \beta_{lk}. \quad (4)$$

Homogeneity is imposed by normalising all the inputs by one input, here input $x_1$:

$$lnD_{Iit} - lnx_{1it} = \alpha_0 + \sum_{m=1}^{M} \alpha_m ln\, y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} lny_{mit} lny_{nit} + \sum_{k=2}^{K} \beta_k ln\, x^*_{kit}$$

$$+\frac{1}{2}\sum_{k=2}^{K}\sum_{l=2}^{K} \beta_{kl} lnx^*_{kit} lnx^*_{lit} + \sum_{k=2}^{K}\sum_{m=1}^{M} \gamma_{km} lnx^*_{kit} lny_{mit}$$

$$+\delta_t t + \frac{1}{2}\delta_{tt} t^2 + \sum_{m=1}^{M} \alpha_{mt} t lny_{mit} + \sum_{k=2}^{K} \beta_{kt} t ln\, x^*_{kit}\,, \quad (5)$$

where $x^*_{kit} = \frac{x_{kit}}{x_{1it}}$.

After introducing statistical error term, $v_{it}$, farm effects, $\mu_i$, and replacing $lnD_{Iit}$ with inefficiency terms, $\eta_i$ and $u_{it}$ ($\eta_i + u_{it} = lnD_{Iit}$) following Kumbhakar et al. (2012) and Colombi et al. (2014), a stochastic frontier multiple input distance function takes the following from:

$$-lnx_{1it} = \alpha_0 + \sum_{m=1}^{M} \alpha_m ln\, y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} lny_{mit} lny_{nit} + \sum_{k=2}^{K} \beta_k ln\, x^*_{kit}$$

$$+\frac{1}{2}\sum_{k=2}^{K}\sum_{l=2}^{K} \beta_{kl} lnx^*_{kit} lnx^*_{lit} + \sum_{k=2}^{K}\sum_{m=1}^{M} \gamma_{km} lnx^*_{kit} lny_{mit}$$

$$+\delta_t t + \frac{1}{2}\delta_{tt}t^2 + \sum_{m=1}^{M}\alpha_{mt} t ln y_{mit} + \sum_{k=2}^{K}\beta_{kt} t ln\, x_{kit}^* + \mu_i + v_{it} - \eta_i - u_{it}\ , \tag{6}$$

where $v_{it}$ is distributed $N(0,\sigma_{vit}^2)$, $u_{it} \sim N^+(0,\sigma_{uit}^2)$ represents time-varying – transient technical inefficiency and $\eta_i \sim N^+(0,\sigma_{\eta i}^2)$ corresponds with persistent technical inefficiency. $\eta_i + u_{it}$ captures overall technical inefficiency. The error components are assumed to be independent of each other and also independent of $x_{it}$.

The input distance function used in this project consists of 3 outputs and 4 inputs. It is estimated separately for the 1995-2003 and 2004-2013 samples. Estimates of the input distance function were used to derive marginal products of inputs which are interpreted as shadow prices of farm factors. According to Färe and Grosskopf (1991) and Grosskopf et al. (1994) marginal products of inputs at the observed input mix can be measured as:

$$w_k^S(\boldsymbol{y},\boldsymbol{x},t) = \frac{\partial D_I(y,x,t)}{\partial x_k}\ . \tag{7}$$

Differences between marginal products of inputs and observed input prices suggest the presence of allocative inefficiency (Karagiannis et al., 2004). The project utilizes this information to evaluate allocative inefficiencies. This part of the analysis is done at the meta level by computing average values of marginal products over sample farms and comparing them with sample average factor prices.

***Derivation of Total Factor Productivity***

Total factor productivity (TFP) measure used in this report is defined as the Törnqvist-Theil index (TTI). TTI is defined as the ratio of the revenue-share weighted geometric mean of individual outputs to the cost-share weighted geometric mean of individual inputs. The logarithmic form of TTI is given by:

$$ln\left(\frac{TFP_{i,t}}{TFP_{i,t-1}}\right) = \frac{1}{2}\sum_m\left[\left(R_{im,t} + R_{im,t-1}\right)ln\left(\frac{y_{im,t}}{y_{im,t-1}}\right)\right] - \frac{1}{2}\sum_k\left[\left(S_{ik,t} + S_{ik,t-1}\right)ln\left(\frac{x_{ik,t}}{x_{ik,t-1}}\right)\right], \tag{8}$$

where $R_m = \frac{p_m y_m}{\sum_m p_m y_m}$ are output revenue shares and $S_k = \frac{w_k x_k}{\sum_k w_k x_k}$ are input cost shares.

The analysis applies the extended version of the TTI index by Caves et al. (1982), which allows for transitive multilateral comparisons. The basic idea of the extension by Caves et al. (1982) is to measure deviations from the sample means in the construction of the index.

Diewert (1976) has shown that the TTI exactly determines changes in production which result from input adjustments when the underlying production technology is described using translog functional form. Consequently, TTI is derived based on parameter estimates of the translog IDF in (6) as the sum of three components: scale effect (SE), technical efficiency effect (TE) and technical change (TCH) effect:

$$\ln TFP_{it} = \underbrace{\ln \iota_{it}}_{SE} + \underbrace{\ln \upsilon_{it}}_{TE} + \underbrace{\ln \tau_{it}}_{TCH}. \tag{9}$$

The scale effect (SE) is measured as the difference between two output indices: the one measured assuming constant returns to scale and the other calculated under the assumption that the underlying technology is characterized by varying returns to scale. After accounting for deviations from the sample means, this results in the following expression:

$$\ln \iota_{it} = \frac{1}{2}\sum_{m=1}^{M}\left[\left(\zeta_{it,m} + \overline{\zeta}_m\right)\left(\ln y_{it,m} - \overline{\ln y_m}\right) + \overline{\zeta}_m \overline{\ln y_m} - \overline{\zeta_{it,m} \ln y_{it,m}}\right], \text{ where} \quad (10)$$

$$\zeta_{it,m} = \left(1 - RTS^{-1}\right)\frac{\partial \ln D_I\left(\mathbf{y}_{it}, \mathbf{x}_{it}^{*}, t; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}\right)}{\partial \ln \mathbf{y}_{it,m}} \text{ with}$$

$RTS^{-1} = \sum_{m=1}^{M} -\frac{\partial \ln D_I\left(\mathbf{y}_{it}, \mathbf{x}_{it}^{*}, t; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}\right)}{\partial t}$ being the inverse of returns to scale.

No aggregation was required to measure the technical efficiency and technical change components as in each case the development of one single variable were to depict. Accordingly, these two components were measured as derivations from the sample means:

$$\ln \tau_{it} = \varphi_{it} - \overline{\varphi_{it}}, \quad (11)$$

$$\ln \upsilon_{it} = \ln TE_{it} - \overline{\ln TE_{it}}, \quad (12)$$

where $\varphi_{it} = -\frac{\partial \ln D_I\left(\mathbf{y}_{it}, \mathbf{x}_{it}^{*}, t; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}\right)}{\partial t}$ is technical change and $TE_{it} = \exp(-u_{it})$ is technical efficiency.

***Estimation procedure***

The project employs a 4-step estimation procedure to obtain parameter estimates of the input distance function and technical efficiency estimates. In the first step, the two-step System Generalised Method of Moments (GMM) estimator (Arellano and Bover, 1995; Blundell and Bond, 1998) is used to obtain consistent estimates of the input distance function while accounting for potential endogeneity.

The endogeneity problem arises when one or more explanatory variables are correlated with the error term, which leads to biased model parameter estimates. Endogeneity might arise in the presence of unobserved heterogeneity of study objects (omitted variable problem), simultaneity and measurement errors (Cameroon and Trivedi, 2005).

GMM estimates the model parameters directly from the moment conditions, without imposing any conditions on the distribution of the error term. It also allows lagged values of model variables to be used as instruments, which is valuable in situations when data do not provide much information on factors of farm heterogeneity. The system GMM estimates a model in both differences and levels and employs two types of instruments: the level instruments for the differenced equations and the lagged differences for the equations in levels (Arellano and Bover, 1995). This makes it more powerful for solving the problem of weak instruments.

In the second step residuals are used from the system GMM level equations to estimate a random effects panel model employing the Generalised Least Squares (GLS) estimator.

The Maximum Likelihood (ML) estimator is used in the third and fourth steps to estimate stochastic frontier models and derive farm transient (the third step) and persistent (the fourth step) technical inefficiencies. To evaluate which factors influence persistent technical efficiency, the approach proposed by Wang (2002) is used to derive average marginal effects of factors explaining heteroscedasticity in the one-sided error term component on unconditional expected value of technical inefficiency.

***IDF parameter estimates***

Annex Table A2 summarises estimates of input distance function parameters by periods and countries, and presents corresponding statistical tests. The translog input distance functions provided good statistical fits for all farm samples. Hansen test statistics indicate the validity of the instruments applied, and the Arellano-Bond autocorrelation test indicates that the null hypothesis of no second-order autocorrelation cannot be rejected (for the Czech Republic the null hypothesis can be rejected at the 10% level of statistical significance only).

For all country samples, most first order parameter estimates are statistically significant at the 1% and 5% significance levels and have the expected sign. A number of second order parameters also obtained statistically significant estimates. Model parameter estimates indicate that the estimated input distance functions are non-increasing in outputs and non-decreasing in inputs for each sample (when evaluated at the sample means). The condition of quasi-concavity of the input distance functions with respect to inputs was satisfied at the sample averages in the majority of cases.

The estimates of the input distance function parameters for the period 2004-2013 for French, West German and English sample farms are in line with the estimates for the earlier period. Disembodied technical change parameters have statistically significant estimates in most cases. Technical change was capital-using in France and England in 1995-2003. It was land-using and labour-saving in France, and labour-using in Germany in the second period according to the model estimates. Technical change was biased towards labour in Hungary and capital in Poland in 2004-2013.

***Derivation of flexibility index and its components***

Flexibility was measured using the following flexibility measure derived by Cremieux et al. (2005) for a multiple output case:

$$Flex = \boldsymbol{y}^T \boldsymbol{C}_{\boldsymbol{yy}} \boldsymbol{y} + 2C(1 - \boldsymbol{1}_{\boldsymbol{J}}^T \boldsymbol{E}_{\boldsymbol{y}}) \tag{13}$$

Where $C$ is the costs function, $\boldsymbol{C}_{\boldsymbol{yy}}$ is the (MxM) Hessian matrix of the cost function with respect to outputs, $\boldsymbol{1}_{\boldsymbol{J}}$ denotes the (1xM) unit vector and $\boldsymbol{E}_{\boldsymbol{y}}$ is the (Mx1) vector of cost elasticities with respect to outputs.

Renner, Glauben and Hockmann (2014) propose to decompose the cost flexibility measure by Cremieux et al. (2005) into three components – the convexity effect, scope effect and scale effect in the following way:

$$Flex = \boldsymbol{y}^T \boldsymbol{C}_{\boldsymbol{yy}}^{Diag} \boldsymbol{y} + \boldsymbol{y}^T \boldsymbol{C}_{\boldsymbol{yy}}^{-\boldsymbol{D}iag} \boldsymbol{y} + 2C\left(1 - \boldsymbol{1}_{\boldsymbol{J}}^T \boldsymbol{E}_{\boldsymbol{y}}\right) \tag{14}$$

In this expression Hessian matrix is split into the matrix containing elements on the principle diagonal, $\boldsymbol{C}_{\boldsymbol{yy}}^{Diag}$, and matrix containing off-diagonal elements, $\boldsymbol{C}_{\boldsymbol{yy}}^{-\boldsymbol{D}iag}$, i.e. $\boldsymbol{C}_{\boldsymbol{yy}} = \boldsymbol{C}_{\boldsymbol{yy}}^{\boldsymbol{D}iag} + \boldsymbol{C}_{\boldsymbol{yy}}^{-Diag}$. Whereas convexity effect defined as $\boldsymbol{y}^T \boldsymbol{C}_{\boldsymbol{yy}}^{Diag} \boldsymbol{y}$, the scope and scale effects correspond with $\boldsymbol{y}^T \boldsymbol{C}_{\boldsymbol{yy}}^{-\boldsymbol{D}iag} \boldsymbol{y}$ and $2C\left(1 - \boldsymbol{1}_{\boldsymbol{J}}^T \boldsymbol{E}_{\boldsymbol{y}}\right)$, respectively.

Using the following relationship between the second-order derivative of the cost function and the distance function provided by Hajargasht, Coelli and Prasada (2008)

$$\boldsymbol{C}_{\boldsymbol{yy}} = C\left[\boldsymbol{D}_{\boldsymbol{y}} \boldsymbol{D}_{\boldsymbol{y}}^{\boldsymbol{T}} - \boldsymbol{D}_{\boldsymbol{yy}} + \boldsymbol{D}_{\boldsymbol{yx}} (\boldsymbol{D}_{\boldsymbol{xx}} + \boldsymbol{D}_{\boldsymbol{x}} \boldsymbol{D}_{\boldsymbol{x}}^{\boldsymbol{T}})^{-1} \boldsymbol{D}_{\boldsymbol{xy}}\right] \tag{15}$$

and the definition of scale efficiency for the input distance function (Färe et al., 1986):

$$Scale = 1 + \boldsymbol{y}^T \boldsymbol{D}_{\boldsymbol{y}} D^{-1}, \tag{16}$$

Renner et al. (2014) derive a measure of flexibility for the input distance function defined as:

$$Flex = (\mathbf{1}_I^T \boldsymbol{D}_x)^{-1} \boldsymbol{y}^T \left[\boldsymbol{D}_y \boldsymbol{D}_y^T - \boldsymbol{D}_{yy} + \boldsymbol{D}_{yx}(\boldsymbol{D}_{xx} + \boldsymbol{D}_x \boldsymbol{D}_x^T)^{-1} \boldsymbol{D}_{xy}\right] \boldsymbol{y} + 2(\mathbf{1}_I^T \boldsymbol{D}_x)^{-1}(1 + \boldsymbol{y}^T \boldsymbol{D}_y D^{-1}) \quad (17)$$

In relation (17), the principal diagonal of the first term, $(\mathbf{1}_I^T \boldsymbol{D}_x)^{-1} \boldsymbol{y}^T \left[\boldsymbol{D}_y \boldsymbol{D}_y^T - \boldsymbol{D}_{yy} + \boldsymbol{D}_{yx}(\boldsymbol{D}_{xx} + \boldsymbol{D}_x \boldsymbol{D}_x^T)^{-1} \boldsymbol{D}_{xy}\right] \boldsymbol{y}$ , represents curvature effect and off-diagonal elements correspond with the scope effect (in an analogy to the relation in (14)). The scale effect finds its expression in the second term, $2(\mathbf{1}_I^T \boldsymbol{D}_x)^{-1}(1 + \boldsymbol{y}^T \boldsymbol{D}_y D^{-1})$.

# Annex B.

# Background tables and figures

### Table B.1. Summary statistics of variables used in the analysis

France, West Germany and England, 1995-2003

| Variable | Description | Measurement unit | France | | West Germany | | England | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Cereals | Cereals output | Euro of 2000 | 63 941.8 | 40 910.9 | 34 758.8 | 25 497.2 | 80 363.9 | 76 026.5 |
| Other crop output | Total crop output except cereals | Euro of 2000 | 31 332.7 | 33 933.6 | 20 578.6 | 25 490.2 | 37 200.4 | 49 784.2 |
| Other farm output | Livestock output and other farm output | Euro of 2000 | 54 388.2 | 69 073.1 | 87 661.3 | 71 214.3 | 72 110.1 | 100 995.2 |
| Materials | Sum of total specific costs and total farming overheads | Euro of 2000 | 92 553.1 | 48 119.0 | 95 148.5 | 54 830.8 | 136 578.5 | 112 420.5 |
| Land | Utilised Agricultural Area, UAA | hectares | 154.7 | 77.6 | 78.8 | 41.8 | 203.4 | 151.3 |
| Labour | Total labour input | Annual work units (AWU) | 1.8 | 0.9 | 1.8 | 0.8 | 2.6 | 1.7 |
| Capital | Sum of depreciation of fixed assets and contract work costs | Euro of 2000 | 40 924.3 | 25 169.7 | 29 213.1 | 15 256.6 | 46 553.3 | 37 855.0 |
| Land rent | Farm rent paid per 1 hectares of rented land; for farms which do not rent land - average rent paid by farms situated in the same NUTS3 region for corresponding year | Euro of 2000 | 41.9 | 45.1 | 375.1 | 275.6 | 825.7 | 512.4 |
| Arable land | Total crops area | hectares | 146.4 | 74.2 | 73.3 | 38.9 | 189.3 | 140.4 |
| Wages | Wage paid divided by AWU for farms with paid labour; NUTS-3 region average wage in the corresponding year otherwise | Euro of 2000 | 17 941.7 | 4 153.8 | 17 245.4 | 7 415.8 | 19 772.4 | 5 207.3 |
| Irrigated land | Irrigated land area | hectares | 3.8 | 17.3 | 0.9 | 43.2 | 0.6 | 6.5 |
| Cereals farm | binary variable: 1 - specialist cereals, oilseeds and protein crops; 0 - other farm type according the Standard Gross Margin (SGM) farm typology | | 0.6 | 0.5 | 0.2 | 0.4 | 0.7 | 0.5 |
| Field crop farm | binary variable: 1 - specialist other fieldcrops; 0 - other farm type according the SGM farm typology | | 0.1 | 0.2 | 0.1 | 0.3 | 0.1 | 0.3 |
| Mixed crop farm | binary variable: 1 - mixed crops farm; 0 - other farm type according the SGM farm typology | | 0.0 | 0.1 | 0.1 | 0.3 | 0.0 | 0.1 |
| Mixed crop and livestock farm | binary variable: 1 - mixed crops and livestock farm; 0 - other farm type according the SGM farm typology | | 0.3 | 0.5 | 0.5 | 0.5 | 0.2 | 0.4 |
| Total subsidies to farm output ratio | Total subsidies excl. on investment divided by farm total output | Euro of 2000 | 0.4 | 0.2 | 0.2 | 0.1 | 0.4 | 0.2 |
| Total subsidies per hectare of UAA | Total subsidies excl. on investment divided by UAA | Euro of 2000 | 334.0 | 63.4 | 364.9 | 106.1 | 352.4 | 87.0 |
| Coupled subsidies per hectare of UAA | Total subsidies excl. on investment minus decoupled subsidies divided by UAA | Euro of 2000 | -- | -- | -- | -- | -- | -- |
| Decoupled subsidies per hectare of UAA | Decoupled subsidies divided by UAA | Euro of 2000 | -- | -- | -- | -- | -- | -- |
| Farmer's age | Farmer's age in the case of individual farm, and AWU-weighted average of farm unpaid farm-holders otherwise | years | 53.1 | 8.8 | 52.4 | 9.7 | 50.9 | 10.7 |
| Farm organisational form | binary variable: 1 - organisational forms other than individual farm; 0 - individual farm | | 0.0 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 |
| Paid AWU share | Share of paid labout in total farm AWU | percent | 15.6 | 27.0 | 13.4 | 21.7 | 29.5 | 26.1 |
| Rented land share | Share of rented land in UAA | percent | 86.7 | 20.7 | 61.7 | 27.6 | 36.5 | 39.9 |
| Investment intensity | Net investment per ha of UAA | Euro of 2000 | 88.1 | 220.3 | 191.3 | 776.9 | 118.8 | 507.9 |
| Contract use share | Contract work costs in total costs | percent | 5.2 | 4.9 | 4.5 | 4.0 | 5.1 | 6.4 |
| Crop production diversification index | Inverse Herfindahl index computed using crop area shares | | 3.0 | 2.5 | 2.7 | 2.4 | 2.8 | 2.5 |
| Livestock output share | Share of livestock output in farm agriculture output | percent | 26.7 | 29.2 | 49.6 | 24.0 | 26.4 | 26.2 |
| Other farm output share | Share of other outputs in farm total output | percent | 5.6 | 7.2 | 9.2 | 10.4 | 9.8 | 10.5 |
| Energy crops' area share | Share of energy crops in total crops area | percent | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Organic farm | binary variable: 1 - fully organic farm, 0 - conventional farm | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Less Favoured Area (LFA) | binary variable: 1 if LFA=2 and more, 0 otherwise | | 0.2 | 0.4 | 0.4 | 0.5 | 0.0 | 0.1 |
| Protein crops' area share | Share of protein crops in total crops area | percent | 5.0 | 6.6 | 1.0 | 3.1 | 5.1 | 7.6 |
| Intensity of fertiliser and plant protection use | Fertiliser and plant protection costs per 1 ha of total crop area | Euro of 2000 | 244.6 | 70.3 | 206.4 | 82.4 | 205.6 | 74.1 |

France, Germany, England, Czech Republic, Hungary and Poland, 2004-13

| Variable | Description | Measurement unit | France | | West Germany | | East Germany | | England | | Czech Republic | | Hungary | | Poland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Cereals | Cereals output | Euro of 2010 | 103,596.8 | 60,682.3 | 52,903.9 | 44,169.8 | 370,697.0 | 471,260.3 | 139,808.0 | 142,629.6 | 235,008.1 | 247,302.5 | 200,646.6 | 388,512.7 | 27,292.0 | 82,394.4 |
| Other crop output | Total crop output except cereals | Euro of 2010 | 61,564.3 | 104,002.8 | 52,501.5 | 92,644.4 | 294,620.7 | 422,732.5 | 107,026.9 | 274,857.3 | 249,962.8 | 298,628.4 | 114,389.7 | 226,129.4 | 18,881.3 | 60,665.7 |
| Other farm output | Livestock output and other farm output | Euro of 2010 | 63,074.6 | 84,025.5 | 55,425.7 | 63,361.1 | 483,990.4 | 932,465.2 | 92,788.4 | 158,682.5 | 367,824.4 | 502,529.5 | 119,655.6 | 352,151.4 | 20,517.6 | 94,532.1 |
| Materials | Sum of total specific costs and total farming overheads | Euro of 2010 | 136,458.0 | 84,438.7 | 105,329.2 | 78,575.4 | 771,138.9 | 1,081,218.0 | 209,410.3 | 283,724.2 | 687,610.4 | 753,351.7 | 283,223.7 | 576,377.2 | 45,108.0 | 152,003.7 |
| Land | Utilised Agricultural Area, UAA | hectares | 183.9 | 94.7 | 94.4 | 58.7 | 760.7 | 800.6 | 228.7 | 208.7 | 833.9 | 795.0 | 441.7 | 684.0 | 68.3 | 186.4 |
| Labour | Total labour input | Annual work units (AWU) | 1.9 | 1.2 | 1.8 | 1.3 | 11.5 | 16.8 | 2.8 | 5.2 | 23.8 | 27.0 | 8.9 | 17.3 | 2.4 | 5.0 |
| Capital | Sum of depreciation of fixed assets and contract work costs | Euro of 2010 | 63,578.6 | 46,348.9 | 35,514.3 | 25,828.6 | 204,334.8 | 261,169.2 | 60,680.4 | 61,075.4 | 132,899.8 | 144,070.0 | 68,578.6 | 123,289.9 | 11,626.3 | 39,237.9 |
| Land rent | Farm rent paid per 1 hectares of rented land; for farms which do not rent land - average rent paid by farms situated in the same NUTS3 region for corresponding year | Euro of 2010 | 136.5 | 35.7 | 240.5 | 79.7 | 159.7 | 51.2 | 245.1 | 78.8 | 53.7 | 21.5 | 90.4 | 27.9 | 63.1 | 36.1 |
| Arable land | Total crops area | hectares | 177.5 | 92.5 | 91.3 | 56.8 | 743.4 | 785.3 | 222.7 | 205.5 | 831.3 | 793.5 | 436.0 | 671.8 | 67.9 | 184.6 |
| Wages | Wage paid divided by AWU for farms with paid labour; NUTS-3 region average wage in the corresponding year otherwise | Euro of 2010 | 20,559.5 | 5,523.7 | 19,075.8 | 6,128.2 | 22,894.1 | 7,209.0 | 25,009.4 | 5,630.0 | 10,846.4 | 2,772.3 | 6,680.1 | 2,630.5 | 4,413.6 | 1,358.7 |
| Irrigated land | Irrigated land area | hectares | 2.8 | 12.1 | 0.2 | 4.0 | 0.6 | 10.5 | 0.4 | 4.4 | 2.3 | 34.2 | 5.8 | 61.8 | 0.1 | 1.3 |
| Cereals farm | binary variable: 1 - specialist cereals, oilseeds and protein crops; 0 - other farm type according the Standard Gross Margin (SGM) farm typology | | 0.6 | 0.5 | 0.3 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.3 | 0.4 | 0.6 | 0.5 | 0.2 | 0.4 |
| Field crop farm | binary variable: 1 - specialist other fieldcrops; 0 - other farm type according the SGM farm typology | | 0.1 | 0.3 | 0.2 | 0.4 | 0.1 | 0.3 | 0.2 | 0.4 | 0.1 | 0.3 | 0.1 | 0.2 | 0.2 | 0.4 |
| Mixed crop farm | binary variable: 1 - mixed crops farm; 0 - other farm type according the SGM farm typology | | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 |
| Mixed crop and livestock farm | binary variable: 1 - mixed crops and livestock farm; 0 - other farm type according the SGM farm typology | | 0.3 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.3 | 0.5 | 0.6 | 0.5 | 0.3 | 0.4 | 0.6 | 0.5 |
| Total subsidies to farm output ratio | Total subsidies excl. on investment divided by farm total output | Euro of 2010 | 0.3 | 0.1 | 0.3 | 0.2 | 0.4 | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 |
| Total subsidies per hectare of UAA | Total subsidies excl. on investment divided by UAA | Euro of 2010 | 352.6 | 59.4 | 378.1 | 113.9 | 363.2 | 67.8 | 350.7 | 108.5 | 274.9 | 85.6 | 244.7 | 100.5 | 280.9 | 211.6 |
| Coupled payments per hectare of UAA | Total subsidies excl. on investment minus decoupled subsidies divided by UAA | Euro of 2010 | 117.8 | 121.7 | 101.3 | 122.4 | 78.1 | 97.4 | 84.8 | 122.6 | -- | -- | -- | -- | -- | -- |
| Decoupled payments per hectare of UAA | Decoupled subsidies divided by UAA | Euro of 2010 | 234.8 | 110.9 | 276.8 | 93.9 | 285.0 | 89.1 | 265.9 | 105.9 | -- | -- | -- | -- | -- | -- |

France, Germany, England, Czech Republic, Hungary and Poland, 2004-13
(*cont'd*)

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farmer's age | Farmer's age in the case of individual farm, and AWU-weighted average of farm unpaid farm-holders otherwise | years | 60.0 | 8.5 | 58.8 | 9.5 | 59.0 | 7.0 | 53.0 | 10.4 | 59.9 | 6.8 | 56.8 | 8.7 | 64.2 | 8.6 |
| Farm organisational form | binary variable: 1 - organisational forms other than individual farm; 0 - individual farm | | 0.6 | 0.5 | 0.0 | 0.2 | 0.5 | 0.5 | 0.1 | 0.3 | 0.5 | 0.5 | 0.3 | 0.5 | 0.0 | 0.1 |
| Paid AWU share | Share of paid labout in total farm AWU | percent | 15.2 | 25.9 | 11.8 | 21.4 | 32.6 | 21.9 | 24.5 | 26.1 | 10.3 | 14.5 | 20.1 | 20.8 | 5.7 | 14.2 |
| Rented land share | Share of rented land in UAA | percent | 91.3 | 17.0 | 63.2 | 27.8 | 77.0 | 19.3 | 41.2 | 38.8 | 79.2 | 25.6 | 60.9 | 36.6 | 28.6 | 26.7 |
| Investment intensity | Net investment per ha of UAA | Euro of 2010 | 121.1 | 326.6 | 218.9 | 719.5 | 139.7 | 322.9 | 172.0 | 603.5 | 100.2 | 248.9 | 92.6 | 234.8 | 123.4 | 354.2 |
| Contract use share | Contract work costs in total costs | percent | 5.3 | 5.1 | 6.1 | 5.5 | 4.8 | 5.1 | 6.5 | 7.8 | 4.1 | 4.7 | 6.2 | 7.0 | 2.8 | 3.9 |
| Crop production diversification index | Inverse Herfindahl index computed using crop area shares | | 2.8 | 1.8 | 2.7 | 1.7 | 2.8 | 2.5 | 3.0 | 2.5 | 3.3 | 2.6 | 3.4 | 4.5 | 2.1 | 1.5 |
| Livestock output share | Share of livestock output in farm agriculture output | percent | 19.0 | 23.0 | 23.8 | 22.7 | 23.4 | 22.6 | 16.8 | 17.7 | 28.7 | 18.7 | 0.1 | 0.2 | 27.7 | 16.4 |
| Other farm output share | Share of other outputs in farm total output | percent | 6.3 | 5.8 | 10.4 | 12.2 | 8.2 | 9.4 | 9.7 | 12.2 | 5.4 | 7.2 | 0.1 | 0.1 | 2.0 | 4.7 |
| Energy crops' area share | Share of energy crops in total crops area | percent | 3.3 | 6.5 | 1.5 | 6.6 | 1.7 | 5.8 | 0.8 | 4.4 | 0.7 | 4.2 | 0.1 | 1.9 | 0.1 | 1.6 |
| Organic farm | binary variable: 1 - fully organic farm, 0 - conventional farm | | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.1 | 0.0 | 0.1 |
| Less Favoured Area (LFA) | binary variable: 1 if LFA=2 and more, 0 otherwise | | 0.2 | 0.4 | 0.4 | 0.5 | 0.3 | 0.5 | 0.0 | 0.1 | 0.4 | 0.5 | 0.3 | 0.4 | 0.5 | 0.5 |
| Protein crops' area share | Share of protein crops in total crops area | percent | 3.0 | 5.1 | 0.9 | 3.5 | 1.9 | 4.0 | 4.3 | 7.0 | 0.6 | 2.3 | 0.6 | 2.7 | 2.8 | 9.0 |
| Intensity of fertiliser and plant protection use | Fertiliser and plant protection costs per 1 ha of total crop area | Euro of 2010 | 317.6 | 100.3 | 287.4 | 159.1 | 250.4 | 115.5 | 279.0 | 124.8 | 158.5 | 80.6 | 150.3 | 87.0 | 177.5 | 96.6 |

**Table B.2. Input distance function parameter estimates for study farms**

France, West Germany and England, 1995-2003

| Variable | France | | West Germany | | England | |
|---|---|---|---|---|---|---|
| Cereals | -0.471 | *** | -0.301 | *** | -0.416 | *** |
| Other crops | -0.102 | *** | -0.114 | *** | -0.151 | *** |
| Other farm output | -0.188 | *** | -0.314 | *** | -0.237 | *** |
| Land | 0.105 | *** | 0.135 | *** | 0.127 | *** |
| Labour | 0.220 | *** | 0.240 | *** | 0.209 | *** |
| Capital | 0.160 | *** | 0.122 | *** | 0.188 | *** |
| Cereals$^2$ | -0.193 | *** | -0.236 | *** | -0.126 | *** |
| Other crop$^2$ | -0.040 | *** | -0.066 | *** | -0.056 | *** |
| Other farm output$^2$ | -0.072 | *** | -0.079 | *** | -0.064 | *** |
| Cereals*Other crops | 0.010 | | -0.005 | | 0.009 | |
| Cereals*Other farm output | 0.006 | | 0.015 | | 0.041 | *** |
| Other crop*Other farm output | 0.021 | *** | 0.025 | ** | 0.041 | *** |
| Land$^2$ | -0.189 | | -0.488 | *** | -0.187 | |
| Labour$^2$ | -0.077 | | -0.436 | *** | 0.078 | |
| Capital$^2$ | 0.131 | *** | 0.080 | * | 0.120 | * |
| Land*Labour | -0.006 | | 0.428 | *** | 0.056 | |
| Land*Capital | -0.031 | | -0.056 | | 0.006 | |
| Labour*Capital | 0.058 | | 0.070 | | -0.066 | |
| Time | 0.005 | *** | 0.009 | *** | 0.020 | *** |
| Time$^2$ | -0.005 | *** | -0.006 | *** | -0.001 | |
| Cereals*Time | 0.006 | | 0.000 | | 0.010 | * |
| Other crops*Time | -0.006 | *** | 0.002 | | 0.003 | |
| Other farm output*Time | 0.001 | | -0.004 | | 0.000 | |
| Land*Time | 0.002 | | -0.003 | | 0.002 | |
| Labour*Time | 0.000 | | -0.011 | | 0.005 | |
| Capital*Time | 0.001 | | -0.011 | ** | -0.023 | *** |
| Cereals*Land | 0.062 | | 0.275 | *** | 0.013 | |
| Other crops*Land | 0.053 | ** | 0.068 | *** | -0.007 | |
| Other farm output*Land | -0.029 | | -0.001 | | -0.020 | |
| Cereals*Labour | -0.135 | *** | -0.279 | *** | -0.079 | |
| Other crops*Labour | -0.049 | ** | -0.067 | ** | 0.064 | ** |
| Other farm output*Labour | -0.018 | | -0.005 | | 0.030 | |
| Cereals*Capital | 0.052 | * | 0.070 | ** | 0.000 | |
| Other crops*Capital | -0.026 | | 0.023 | | -0.002 | |
| Other farm output*Capital | 0.008 | | 0.002 | | 0.053 | *** |
| Constant | 0.062 | *** | 0.143 | *** | 0.146 | *** |
| Number of observations | 7 850 | | 4 706 | | 2 671 | |
| Number of instruments | 983 | | 782 | | 491 | |
| F-test | 388.3 (38, 1 099) | | 425.0 (37, 731) | | 270.8 (35, 420) | |
| AR(2)-test | 1.02 | | -0.30 | | 0.63 | |
| Hansen test of over identifying restrictions | 995.43 (944) | | 705.17 (744) | | 398.30 (455) | |

France, Germany and England, 2004-13

| Variable | France | | Germany | | | | England | |
|---|---|---|---|---|---|---|---|---|
| | | | West Germany | | East Germany | | | |
| Cereals | *-0.428* | *** | -0.290 | *** | -0.349 | *** | -0.447 | *** |
| Other crops | *-0.166* | *** | -0.222 | *** | -0.256 | *** | -0.214 | *** |
| Other farm output | *-0.194* | *** | -0.205 | *** | -0.255 | *** | -0.168 | *** |
| Land | *0.127* | *** | 0.132 | *** | 0.065 | * | 0.170 | *** |
| Labour | *0.204* | *** | 0.254 | *** | 0.116 | *** | 0.160 | *** |
| Capital | *0.160* | *** | 0.104 | *** | 0.162 | *** | 0.096 | *** |
| Cereals$^2$ | *-0.216* | *** | -0.118 | *** | -0.083 | *** | -0.208 | *** |
| Other crop$^2$ | *-0.067* | *** | -0.087 | *** | -0.071 | *** | -0.137 | *** |
| Other farm output$^2$ | *-0.086* | *** | -0.052 | *** | -0.061 | *** | -0.040 | *** |
| Cereals*Other crops | *0.026* | | 0.067 | *** | 0.026 | ** | 0.139 | *** |
| Cereals*Other farm output | *0.004* | | 0.023 | *** | 0.020 | | 0.016 | |
| Other crop*Other farm output | *0.027* | *** | 0.026 | *** | 0.020 | ** | -0.002 | |
| Land$^2$ | *-0.343* | ** | -0.185 | ** | -0.060 | | -0.009 | |
| Labour$^2$ | *-0.008* | | 0.008 | | -0.021 | | 0.092 | * |
| Capital$^2$ | *0.094* | * | 0.066 | ** | 0.122 | * | 0.014 | |
| Land*Labour | *-0.010* | | 0.165 | *** | 0.050 | | -0.018 | |
| Land*Capital | *-0.017* | | 0.080 | * | -0.087 | | 0.036 | |
| Labour*Capital | *0.014* | | -0.111 | *** | -0.056 | | -0.087 | |
| Time | *-0.004* | *** | -0.004 | *** | -0.008 | *** | -0.012 | *** |
| Time$^2$ | *-0.012* | *** | 0.005 | *** | 0.014 | *** | -0.021 | *** |
| Cereals*Time | *-0.001* | | -0.003 | | 0.006 | | 0.021 | *** |
| Other crops*Time | *0.001* | | -0.006 | *** | -0.010 | *** | -0.018 | *** |
| Other farm output*Time | *-0.001* | | 0.001 | | 0.004 | ** | 0.004 | * |
| Land*Time | *-0.017* | *** | -0.007 | | -0.003 | | 0.001 | |
| Labour*Time | *0.012* | *** | -0.011 | ** | -0.005 | | 0.005 | |
| Capital*Time | *-0.001* | | -0.001 | | 0.004 | | -0.006 | |
| Cereals*Land | *0.067* | | 0.100 | *** | 0.031 | | 0.019 | |
| Other crops*Land | *0.087* | *** | -0.004 | | 0.060 | | 0.002 | |
| Other farm output*Land | *-0.041* | | 0.005 | | -0.005 | | -0.002 | |
| Cereals*Labour | *-0.090* | ** | -0.069 | *** | -0.009 | | 0.024 | |
| Other crops*Labour | *-0.073* | *** | 0.010 | | -0.022 | | -0.034 | |
| Other farm output*Labour | *-0.029* | * | 0.021 | | -0.031 | * | -0.026 | |
| Cereals*Capital | *0.031* | | -0.064 | *** | -0.040 | | -0.002 | |
| Other crops*Capital | *-0.028* | | 0.004 | | -0.033 | | 0.008 | |
| Other farm output*Capital | *0.015* | | 0.013 | | -0.002 | | -0.016 | |
| Constant | *0.000* | *** | 0.081 | *** | 0.110 | *** | 0.275 | *** |
| Number of observations | *6 983* | | 6 725 | | 4 764 | | 2 118 | |
| Number of instruments | *1 036* | | 908 | | 606 | | 699 | |
| F-test | *498.7 (38, 895)* | | 460.0 (38, 930) | | 837.0 (37, 650) | | 424.2 (38, 307) | |
| AR(2)-test | *0.19* | | 0.14 | | 0.38 | | -1.30 | |
| Hansen test of over identifying restrictions | *868.92 (997)* | | 883.42 (869) | | 606.81 (568) | | 275.76 (660) | |

The Czech Republic, Hungary and Poland, 2004-13

| Variable | Czech Republic | | Hungary | | Poland | |
|---|---|---|---|---|---|---|
| Cereals | -0.364 | *** | -0.437 | *** | -0.334 | *** |
| Other crops | -0.314 | *** | -0.265 | *** | -0.170 | *** |
| Other farm output | -0.283 | *** | -0.195 | *** | -0.178 | *** |
| Land | 0.072 | * | 0.150 | *** | 0.093 | *** |
| Labour | 0.134 | *** | 0.115 | *** | 0.311 | *** |
| Capital | 0.080 | *** | 0.176 | *** | 0.100 | *** |
| $Cereals^2$ | -0.102 | *** | -0.107 | *** | -0.090 | *** |
| Other $crop^2$ | -0.108 | *** | -0.055 | *** | -0.060 | *** |
| Other farm $output^2$ | -0.067 | *** | -0.056 | *** | -0.049 | *** |
| Cereals*Other crops | 0.070 | *** | 0.038 | *** | 0.020 | ** |
| Cereals*Other farm output | 0.044 | *** | 0.034 | *** | -0.002 | |
| Other crop*Other farm output | 0.020 | | 0.003 | | 0.019 | *** |
| $Land^2$ | -0.007 | | -0.033 | | -0.231 | *** |
| $Labour^2$ | 0.005 | | -0.015 | | 0.086 | |
| $Capital^2$ | 0.075 | ** | 0.081 | ** | -0.051 | |
| Land*Labour | 0.108 | | -0.073 | | 0.030 | |
| Land*Capital | -0.141 | ** | 0.036 | | 0.117 | ** |
| Labour*Capital | 0.002 | | 0.017 | | -0.007 | |
| Time | -0.016 | *** | -0.026 | *** | -0.016 | *** |
| $Time^2$ | -0.003 | ** | 0.003 | * | -0.003 | *** |
| Cereals*Time | 0.001 | | 0.014 | *** | -0.006 | * |
| Other crops*Time | -0.006 | * | -0.015 | *** | 0.002 | |
| Other farm output*Time | 0.007 | ** | -0.001 | | 0.001 | |
| Land*Time | -0.002 | | -0.007 | | 0.005 | |
| Labour*Time | 0.003 | | -0.013 | ** | 0.001 | |
| Capital*Time | -0.008 | | 0.003 | | -0.009 | ** |
| Cereals*Land | 0.135 | ** | 0.028 | | -0.020 | |
| Other crops*Land | -0.065 | | -0.077 | *** | 0.006 | |
| Other farm output*Land | 0.002 | | -0.014 | | 0.004 | |
| Cereals*Labour | 0.021 | | -0.054 | | 0.017 | |
| Other crops*Labour | -0.016 | | 0.035 | * | -0.003 | |
| Other farm output*Labour | -0.015 | | -0.034 | * | -0.014 | |
| Cereals*Capital | 0.016 | | 0.050 | ** | -0.008 | |
| Other crops*Capital | 0.020 | | -0.015 | | 0.002 | |
| Other farm output*capital | -0.041 | ** | 0.002 | | 0.019 | |
| Constant | 0.180 | *** | 0.125 | *** | 0.162 | *** |
| Number of observations | 2 661 | | 4 084 | | 8 339 | |
| Number of instruments | 415 | | 602 | | 1 050 | |
| F-test | 1 672.8 (37, 428) | | 856.82 (36, 537) | | 1 564.11 (37, 1 118) | |
| AR(2)-test | -1.95 | | -1.50 | | -0.05 | |
| Hansen test of over identifying restrictions | 399.50 (377) | | 518.40 (565) | | 1 069.18 (1 012) | |

*Note*: ***, ** and * - statistically significant at the 1, 5 and 10% level, respectively

**Table B.3. TFP change decomposition: Annual averages for sample farms by countries and periods**

**France, 1995-2013**

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 1996 | 0.015 | 0.005 | 0.010 | 0.000 |
| 1997 | 0.009 | 0.006 | 0.003 | 0.000 |
| 1998 | 0.009 | 0.004 | 0.004 | 0.000 |
| 1999 | 0.001 | 0.005 | -0.004 | 0.000 |
| 2000 | 0.007 | 0.005 | 0.002 | 0.000 |
| 2001 | 0.001 | 0.005 | -0.004 | 0.000 |
| 2002 | 0.015 | 0.005 | 0.009 | 0.000 |
| 2003 | 0.000 | 0.006 | -0.006 | 0.000 |
| Mean 1996-2003 | 0.007 | 0.005 | 0.002 | 0.000 |
| 2005 | 0.016 | 0.012 | 0.004 | 0.001 |
| 2006 | 0.007 | 0.013 | -0.005 | 0.000 |
| 2007 | 0.009 | 0.013 | -0.004 | 0.000 |
| 2008 | 0.012 | 0.012 | -0.001 | 0.001 |
| 2009 | 0.018 | 0.012 | 0.004 | 0.001 |
| 2010 | 0.018 | 0.013 | 0.004 | 0.001 |
| 2011 | 0.006 | 0.013 | -0.005 | -0.001 |
| 2012 | 0.016 | 0.013 | 0.002 | 0.001 |
| 2013 | -0.003 | 0.014 | -0.015 | 0.000 |
| Mean 2005-2013 | 0.011 | 0.013 | -0.002 | 0.000 |

West Germany, 1995-2013

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 1996 | 0.007 | 0.006 | 0.001 | 0.000 |
| 1997 | 0.015 | 0.006 | 0.009 | 0.000 |
| 1998 | -0.001 | 0.005 | -0.006 | 0.000 |
| 1999 | 0.019 | 0.007 | 0.013 | 0.000 |
| 2000 | 0.009 | 0.007 | 0.003 | -0.001 |
| 2001 | 0.002 | 0.006 | -0.003 | -0.001 |
| 2002 | -0.003 | 0.004 | -0.007 | 0.000 |
| 2003 | 0.011 | 0.007 | 0.006 | -0.002 |
| Mean 1996-2003 | 0.007 | 0.006 | 0.002 | -0.001 |
| 2005 | 0.005 | -0.004 | 0.010 | 0.000 |
| 2006 | -0.018 | -0.005 | -0.011 | -0.001 |
| 2007 | -0.020 | -0.006 | -0.009 | -0.005 |
| 2008 | -0.013 | -0.004 | -0.012 | 0.002 |
| 2009 | 0.021 | -0.004 | 0.027 | -0.002 |
| 2010 | 0.001 | -0.005 | 0.003 | 0.003 |
| 2011 | -0.041 | -0.006 | -0.028 | -0.009 |
| 2012 | -0.003 | -0.004 | 0.002 | -0.001 |
| 2013 | -0.007 | -0.005 | -0.004 | 0.001 |
| Mean 2005-2013 | -0.008 | -0.005 | -0.002 | -0.001 |

East Germany, 2004-13

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 2005 | 0.005 | -0.015 | 0.007 | 0.013 |
| 2006 | -0.015 | -0.014 | 0.006 | -0.008 |
| 2007 | -0.032 | -0.015 | 0.001 | -0.018 |
| 2008 | 0.009 | -0.010 | 0.004 | 0.016 |
| 2009 | 0.007 | -0.011 | 0.019 | 0.000 |
| 2010 | -0.011 | -0.015 | -0.012 | 0.016 |
| 2011 | -0.048 | -0.013 | -0.011 | -0.026 |
| 2012 | 0.009 | -0.012 | 0.008 | 0.015 |
| 2013 | -0.014 | -0.012 | 0.003 | -0.005 |
| Mean 2005-2013 | -0.010 | -0.013 | 0.003 | 0.000 |

England, 1995-2013

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 1996 | 0.013 | 0.003 | 0.015 | -0.005 |
| 1997 | 0.026 | 0.003 | 0.024 | -0.001 |
| 1998 | 0.012 | 0.000 | 0.006 | 0.006 |
| 1999 | 0.008 | 0.001 | 0.007 | 0.000 |
| 2000 | 0.004 | 0.000 | 0.005 | -0.001 |
| 2001 | -0.037 | 0.003 | -0.005 | -0.033 |
| 2002 | 0.048 | -0.003 | 0.015 | 0.033 |
| 2003 | -0.003 | 0.001 | 0.003 | -0.007 |
| Mean 1996-2003 | 0.009 | 0.001 | 0.009 | -0.001 |
| 2005 | 0.042 | 0.024 | 0.007 | 0.011 |
| 2006 | 0.029 | 0.018 | 0.007 | 0.002 |
| 2007 | 0.005 | 0.020 | -0.006 | -0.007 |
| 2008 | -0.001 | 0.030 | -0.034 | 0.006 |
| 2009 | 0.033 | 0.026 | 0.006 | 0.001 |
| 2010 | 0.045 | 0.019 | 0.020 | 0.003 |
| 2011 | -0.006 | 0.029 | -0.028 | -0.002 |
| 2012 | 0.025 | 0.026 | -0.002 | 0.002 |
| 2013 | -0.022 | 0.029 | -0.042 | 0.001 |
| Mean 2005-2013 | 0.017 | 0.024 | -0.008 | 0.002 |

Czech Republic, 2004-13

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 2005 | 0.029 | 0.004 | 0.002 | 0.023 |
| 2006 | -0.015 | 0.003 | -0.004 | -0.014 |
| 2007 | 0.003 | 0.005 | -0.001 | -0.001 |
| 2008 | 0.014 | 0.004 | 0.002 | 0.007 |
| 2009 | 0.009 | 0.004 | 0.004 | 0.001 |
| 2010 | 0.018 | 0.003 | -0.002 | 0.016 |
| 2011 | -0.007 | 0.004 | 0.002 | -0.013 |
| 2012 | 0.009 | 0.004 | -0.001 | 0.006 |
| 2013 | 0.004 | 0.004 | -0.001 | 0.002 |
| Mean 2005-2013 | 0.007 | 0.004 | 0.000 | 0.003 |

Hungary, 2004-13

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 2005 | 0.007 | -0.002 | 0.005 | 0.002 |
| 2006 | -0.023 | -0.003 | 0.000 | -0.021 |
| 2007 | -0.092 | -0.005 | -0.002 | -0.085 |
| 2008 | 0.108 | 0.001 | -0.005 | 0.112 |
| 2009 | -0.037 | -0.001 | -0.002 | -0.036 |
| 2010 | 0.015 | -0.006 | -0.003 | 0.024 |
| 2011 | 0.000 | -0.002 | 0.000 | 0.003 |
| 2012 | -0.054 | -0.002 | -0.002 | -0.053 |
| 2013 | 0.038 | 0.001 | -0.002 | 0.041 |
| Mean 2005-2013 | -0.004 | -0.002 | -0.001 | -0.001 |

Poland, 2004-013

| Year | TFP change | Technical change | Scale effect | Technical efficiency change |
|---|---|---|---|---|
| 2005 | 0.037 | 0.004 | 0.029 | 0.003 |
| 2006 | 0.003 | 0.003 | 0.005 | -0.004 |
| 2007 | -0.027 | 0.003 | -0.023 | -0.008 |
| 2008 | 0.005 | 0.003 | -0.007 | 0.009 |
| 2009 | -0.012 | 0.002 | -0.015 | 0.000 |
| 2010 | 0.042 | 0.005 | 0.026 | 0.011 |
| 2011 | -0.056 | 0.003 | -0.040 | -0.017 |
| 2012 | 0.014 | 0.003 | 0.003 | 0.008 |
| 2013 | 0.000 | 0.003 | -0.003 | 0.001 |
| Mean 2005-2013 | 0.001 | 0.003 | -0.003 | 0.000 |

*Note*: 1) For the technical efficiency component positive values indicate improvement of technical inefficiency while negative values correspond with a decrease in technical efficiency.

**Table B.4. Determinants of TFP change: RE Tobit model estimates, specification with subsidies to farm output ratio, 1995-2003 and 2004-13**

| Variables | France, 1995-2003 | Germany, 1995-2003 | England, 1995-2003 | France, 2004-2013 | Germany, 2004-2013 | | England, 2004-2013 | Czech Republic, 2004-2013 | Hungary, 2004-2013 | Poland, 2004-2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | West Germany | East Germany | | | | |
| Farm size, hectares of UAA | 0.0007 *** | 0.0024 *** | 0.0006 *** | 0.0004 *** | 0.0023 *** | 0.0001 *** | 0.0002 *** | 0.0001 *** | -0.0001 *** | 0.0003 *** |
| Total subsidies per output | -0.2123 *** | -0.4271 *** | -0.36270 *** | -0.2900 *** | -0.4211 *** | -0.3491 *** | -0.3482 *** | -0.1801 *** | -0.3984 *** | -0.2509 *** |
| Farmer's age | 0.0003 *** | 0.0006 *** | -0.0001 | 0.0003 | 0.0006 *** | 0.0005 * | 0.0004 | -0.0003 * | 0.0015 *** | 0.0010 *** |
| Farm organisational form[1)] | -- | 0.0238 *** | -0.0076 | -- | 0.0037 | -- | -0.0029 | -- | -- | -- |
| Paid AWU share | -0.00004 | -0.0001 ** | 0.0001 | 0.00003 | 0.0002 *** | 0.0001 * | 0.0001 | -0.0001 | 0.0006 *** | 0.0003 ** |
| Rented land share | 0.0003 *** | 0.00002 | -0.00001 | 0.0004 *** | 0.0003 *** | 0.0002 * | 0.0003 ** | -0.0004 *** | 0.0009 *** | 0.0016 *** |
| Investment intensity, lag 1 | -0.000001 | 0.000002 * | -0.00001 *** | 0.000004 *** | -0.0000003 | -0.000001 | -0.000001 | 0.000007 * | -0.00002 ** | 0.00001 *** |
| Investment intensity, lag 2 | 0.000001 | 0.000001 | -0.000001 | 0.000004 ** | 0.000002 * | -0.000004 | -0.000001 | 0.000006 | 0.000002 | 0.00001 *** |
| Contract use share | -0.0001 | -0.0003 | 0.0009 *** | -0.0001 | -0.00005 | -0.0004 | 0.0012 *** | 0.0001 | -0.0012 ** | -0.0013 *** |
| Crop production diversification index | -0.0018 ** | -0.0032 *** | -0.0008 | 0.0002 | 0.0004 | -0.0009 | 0.0010 | 0.0048 *** | 0.0036 *** | 0.0003 |
| Livestock output share | -0.0003 *** | 0.0005 *** | 0.0005 *** | -0.0001 | 0.0014 *** | -0.0005 *** | -0.0013 *** | -0.0001 | -0.2333 *** | -0.0008 *** |
| Other farm output share | 0.0001 | 0.0002 | 0.0014 *** | -0.0005 *** | 0.0009 *** | -0.0008 *** | -0.0011 *** | 0.0003 ** | 0.0411 | -0.0002 |
| Energy crops' area share | -- | -- | -- | 0.0001 | 0.0007 *** | -0.0002 | -0.0002 | 0.0001 | 0.0010 | -0.0003 |
| Organic farm | -- | -- | -- | -0.0153 *** | -0.0467 ** | 0.0076 | -0.0300 ** | 0.0001 | 0.0386 | 0.0125 |
| LFA | -0.00563 ** | 0.0063 | -0.0088 | -0.0057 | -0.0140 *** | 0.0076 | -0.0285 | 0.0139 *** | 0.0134 | 0.0105 |
| year 1998 | 0.0143 *** | 0.0170 *** | 0.0182 *** | -- | -- | -- | -- | -- | -- | -- |
| year 1999 | 0.0210 *** | 0.0347 *** | 0.0436 *** | -- | -- | -- | -- | -- | -- | -- |
| year 2000 | 0.0201 *** | 0.0325 *** | 0.0426 *** | -- | -- | -- | -- | -- | -- | -- |
| year 2001 | 0.0263 *** | 0.0277 *** | -0.0022 | -- | -- | -- | -- | -- | -- | -- |
| year 2002 | 0.0428 *** | 0.0383 *** | 0.0476 *** | -- | -- | -- | -- | -- | -- | -- |
| year 2003 | 0.0392 *** | 0.0374 *** | 0.0287 *** | -- | -- | -- | -- | -- | -- | -- |
| year 2007 | -- | -- | -- | -0.0222 *** | -0.0638 *** | -0.0792 *** | -0.0228 *** | -0.0127 *** | -0.1339 *** | -0.0361 *** |
| year 2008 | -- | -- | -- | -0.0099 *** | -0.0734 *** | -0.0593 *** | -0.0364 *** | 0.0116 *** | 0.0043 | -0.0095 ** |
| year 2009 | -- | -- | -- | 0.0291 *** | -0.0059 * | -0.0264 *** | 0.0159 *** | 0.0380 *** | 0.0036 | 0.0106 ** |
| year 2010 | -- | -- | -- | 0.0225 *** | -0.0319 *** | -0.0544 *** | 0.0398 *** | 0.0446 *** | 0.0204 ** | 0.0294 *** |
| year 2011 | -- | -- | -- | 0.0132 *** | -0.1050 *** | -0.1215 *** | 0.0208 *** | 0.0190 *** | -0.0037 | -0.0518 *** |
| year 2012 | -- | -- | -- | 0.0301 *** | -0.1183 *** | -0.1251 *** | 0.0446 *** | 0.0269 *** | -0.0752 *** | -0.0399 *** |
| year 2013 | -- | -- | -- | 0.0263 *** | -0.1127 *** | -0.1268 *** | 0.0382 *** | 0.0367 *** | -0.0032 | -0.0334 *** |
| Bassin parisien | -0.0065 | -- | -- | -0.0005 | -- | -- | -- | -- | -- | -- |
| Nord-Pas-de-Calais | -0.0446 *** | -- | -- | -0.0579 *** | -- | -- | -- | -- | -- | -- |
| Est | -0.0071 | -- | -- | -0.0033 | -- | -- | -- | -- | -- | -- |
| Reference region: Île de France | 0.9436 *** | -- | -- | 0.9613 ** | -- | -- | -- | -- | -- | -- |

**Table B.4. Determinants of TFP change: RE Tobit model estimates, specification with subsidies to farm output ratio, 1995-2003 and 2004-13 (*cont'd*)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bayern | -- | -0.0107 | -- | -- | 0.0057 | -- | -- | -- | -- | -- |
| Hessen | -- | -0.0349 *** | -- | -- | -0.0302 ** | -- | -- | -- | -- | -- |
| Niedersachsen | -- | -0.0250 ** | -- | -- | 0.0297 *** | -- | -- | -- | -- | -- |
| Nordrhein-Westfalen | -- | 0.0195 | -- | -- | 0.0221 * | -- | -- | -- | -- | -- |
| Rheinland-Pfalz | -- | -0.0466 *** | -- | -- | -0.0498 *** | -- | -- | -- | -- | -- |
| Saarland | -- | -0.0648 *** | -- | -- | -0.0711 *** | -- | -- | -- | -- | -- |
| Schleswig-Holstein | -- | 0.0030 | -- | -- | 0.0308 ** | -- | -- | -- | -- | -- |
| Reference region: Baden-Württemberg | -- | 0.8594 *** | -- | -- | 0.8660 *** | -- | -- | -- | -- | -- |
| Mecklenburg-Vorpommern | -- | -- | -- | -- | -- | 0.0157 | -- | -- | -- | -- |
| Sachsen | -- | -- | -- | -- | -- | -0.0205 | -- | -- | -- | -- |
| Sachsen-Anhalt | -- | -- | -- | -- | -- | -0.0004 | -- | -- | -- | -- |
| Thüringen | -- | -- | -- | -- | -- | -0.0359 ** | -- | -- | -- | -- |
| Reference region: Brandenburg | -- | -- | -- | -- | -- | 1.1229 *** | -- | -- | -- | -- |
| North West (England) | -- | -- | -0.0728 *** | -- | -- | -- | -0.0225 | -- | -- | -- |
| Yorkshire And The Humber | -- | -- | 0.0080 | -- | -- | -- | -0.0194 | -- | -- | -- |
| East Midlands (England) | -- | -- | 0.0028 | -- | -- | -- | -0.0290 | -- | -- | -- |
| West Midlands (England) | -- | -- | 0.0025 | -- | -- | -- | 0.0020 | -- | -- | -- |
| East of England | -- | -- | 0.0043 | -- | -- | -- | -0.0083 | -- | -- | -- |
| South East (England) | -- | -- | -0.0024 | -- | -- | -- | -0.0063 | -- | -- | -- |
| South West (England) | -- | -- | -0.0122 | -- | -- | -- | -0.0047 | -- | -- | -- |
| Reference region: North East (England) | -- | -- | 0.9965 *** | -- | -- | -- | 1.0557 *** | -- | -- | -- |
| Jihozápad | -- | -- | -- | -- | -- | -- | -- | 0.0016 | -- | -- |
| Severozápad | -- | -- | -- | -- | -- | -- | -- | -0.0070 | -- | -- |
| Severovýchod | -- | -- | -- | -- | -- | -- | -- | 0.0027 | -- | -- |
| Jihovýchod | -- | -- | -- | -- | -- | -- | -- | 0.0003 | -- | -- |
| Střední Morava | -- | -- | -- | -- | -- | -- | -- | 0.0069 | -- | -- |
| Reference region: Praha | -- | -- | -- | -- | -- | -- | -- | 0.9945 *** | -- | -- |

**Table B.4. Determinants of TFP change: RE Tobit model estimates, specification with subsidies to farm output ratio, 1995-2003 and 2004-13 (*cont'd*)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Közép-Dunántúl | -- | -- | -- | -- | -- | -- | -- | -- | -0.0069 | -- |
| Nyugat-Dunántúl | -- | -- | -- | -- | -- | -- | -- | -- | 0.0113 | -- |
| Dél-Dunántúl | -- | -- | -- | -- | -- | -- | -- | -- | -0.0236 | -- |
| Észak-Magyarország | -- | -- | -- | -- | -- | -- | -- | -- | 0.0098 | -- |
| Észak-Alföld | -- | -- | -- | -- | -- | -- | -- | -- | -0.0051 | -- |
| Dél-Alföld | -- | -- | -- | -- | -- | -- | -- | -- | 0.0101 | -- |
| Reference region: Közép-Magyarország | -- | -- | -- | -- | -- | -- | -- | -- | 1.0679 *** | -- |
| Region Południowy | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1040 *** |
| Region Wschodni | -- | -- | -- | -- | -- | -- | -- | -- | -- | -0.0155 |
| Region Pólnocno-Zachodni | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1689 *** |
| Region Południowo-Zachodni | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1275 *** |
| Region Pólnocny | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.2125 *** |
| Reference region: Centralny | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.9192 *** |
| sigma u | 0.0538 *** | 0.0722 *** | 0.0729 *** | 0.0636 *** | 0.0831 *** | 0.1145 *** | 0.0868 *** | 0.0224 *** | 0.1310 *** | 0.1978 *** |
| sigma e | 0.0286 *** | 0.0366 *** | 0.0453 *** | 0.0309 *** | 0.0452 *** | 0.0437 *** | 0.0354 *** | 0.0324 *** | 0.1006 *** | 0.0645 *** |
| Number of observations | 4596 | 3031 | 1709 | 4823 | 4555 | 3232 | 1407 | 2084 | 2812 | 5695 |
| Log likelihood | 8482.7 | 4733.4 | 2371.2 | 8568.9 | 6370.0 | 4410.6 | 2210.3 | 3945.2 | 1875.2 | 5413.8 |
| LR test: sigma u=0 | 3745.8 | 2333.5 | 906.4 | 4692.3 | 3406.0 | 3949.0 | 1509.4 | 262.5 | 1227.7 | 7188.6 |

*Note*: 1. All model variables are the same as in the model specification presented in table 4 of the report except the subsidy variable which is measured per 1 Euro of farm output

***, ** and * - statistically significant at the 1, 5 and 10 percent level, respectively

**Table B.5. Average marginal effects of selected factors on unconditional expected value of persistent technical inefficiency: Estimates of SF model with heteroscedasticity, specification with subsidies to farm output ratio, 2004-13**

France, West Germany and England, 1995-2003

| Variable | France | West Germany | England |
|---|---|---|---|
| Farm size, hectares of UAA | 0.0003 *** | 0.0005 *** | 0.0001 *** |
| Total subsidies per output | 0.1576 *** | 0.0730 *** | 0.2881 *** |
| Farmer's age | -0.0008 ** | -0.0011 *** | -0.0026 |
| Paid AWU share | 0.0002 | -0.00005 | 0.0003 |
| Rented land share | 0.0001 | -0.0002 | -0.0002 |
| Investment intensity | -0.00003 | -0.00005 | 0.0000 |
| Contract use share | 0.0013 | 0.0015 | -0.0003 |
| Crop production diversification index | 0.0004 | 0.0013 | 0.0045 |
| Livestock output share | 0.0005 ** | 0.0001 | 0.0009 ** |
| Other farm output share | -0.0018 ** | -0.0007 | -0.0003 |
| LFA | -0.0462 | 0.0482 *** | -0.0376 |
| Bassin parisien | -0.0659 *** | -- | -- |
| Nord-Pas-de-Calais | -0.0898 ** | -- | -- |
| Est | -0.0721 *** | -- | -- |
| Reference region: Île de France | -- | -- | -- |
| Bayern | -- | 0.0239 | -- |
| Hessen | -- | 0.0258 | -- |
| Niedersachsen | -- | 0.0342 * | -- |
| Nordrhein-Westfalen | -- | 0.0021 | -- |
| Rheinland-Pfalz | -- | 0.0008 | -- |
| Saarland | -- | -0.0218 | -- |
| Schleswig-Holstein | -- | 0.0074 | -- |
| Reference region: Baden-Württemberg | -- | -- | -- |
| North West (England) | -- | -- | 0.0731 ** |
| Yorkshire And The Humber | -- | -- | -0.0525 |
| East Midlands (England) | -- | -- | -0.0247 |
| West Midlands (England) | -- | -- | -0.0262 |
| East of England | -- | -- | 0.0256 |
| South East (England) | -- | -- | 0.0467 *** |
| South West (England) | -- | -- | 0.0007 |
| Reference region: North East (England) | -- | -- | -- |
| Number of observations | 1 036 | 732 | 421 |
| Likelihood ratio test (H0: $\sigma u = 0$) | 224.4 *** | 177.4 *** | 135.8 *** |

France, Germany and England, 2004-13

| Variable | France | Germany | | England |
|---|---|---|---|---|
| | | West Germany | East Germany | |
| Farm size, hectares of UAA | 0.0002 *** | 0.0004 *** | 0.00001 *** | 0.0001 * |
| Total subsidies per output | 0.1809 | 0.1570 *** | 0.0584 | 0.1811 *** |
| Farmer's age | 0.0004 ** | -0.0012 *** | -0.0002 *** | -0.0013 ** |
| Farm organisational form | -- | 0.0457 *** | -- | 0.0475 ** |
| Paid AWU share | 0.0005 *** | 0.0008 *** | 0.0004 *** | 0.0001 |
| Rented land share | -0.0003 *** | 0.0002 | 0.0001 *** | -0.0002 |
| Investment intensity | -0.00001 *** | 0.00002 | -0.0001 *** | -0.00002 |
| Contract use share | -0.0001 ** | -0.0020 ** | -0.0012 *** | -0.0009 |
| Crop production diversification index | 0.0026 * | 0.0070 ** | -0.0029 *** | 0.0033 |
| Livestock output share | -0.0007 ** | 0.0002 | 0.0001 *** | 0.0004 |
| Other farm output share | -0.0043 ** | -0.0005 | 0.0006 *** | -0.0003 |
| Organic farm | 0.0514 | -0.0433 | 0.0431 *** | -0.0750 |
| LFA | 0.0240 | 0.0251 ** | 0.0962 | 0.0052 |
| Bassin parisien | 0.0072 | -- | -- | -- |
| Nord-Pas-de-Calais | -0.0165 | -- | -- | -- |
| Est | -0.0009 | -- | -- | -- |
| Reference region: Île de France | -- | -- | -- | -- |
| Bayern | -- | -0.0116 | -- | -- |
| Hessen | -- | -0.0327 ** | -- | -- |
| Niedersachsen | -- | 0.0247 * | -- | -- |
| Nordrhein-Westfalen | -- | -0.1608 *** | -- | -- |
| Rheinland-Pfalz | -- | 0.0039 | -- | -- |
| Saarland | -- | 0.0414 ** | -- | -- |
| Schleswig-Holstein | -- | -0.0528 *** | -- | -- |
| Reference region: Baden-Württemberg | -- | -- | -- | -- |
| Mecklenburg-Vorpommern | -- | -- | 0.0110 *** | -- |
| Sachsen | -- | -- | 0.0068 *** | -- |
| Sachsen-Anhalt | -- | -- | 0.0045 *** | -- |
| Thüringen | -- | -- | -0.0118 *** | -- |
| Reference region: Brandenburg | -- | -- | -- | -- |
| North West (England) | -- | -- | -- | 0.0345 |
| Yorkshire And The Humber | -- | -- | -- | -0.0112 |
| East Midlands (England) | -- | -- | -- | -0.0117 |
| West Midlands (England) | -- | -- | -- | -0.0394 |
| East of England | -- | -- | -- | -0.0001 |
| South East (England) | -- | -- | -- | 0.0147 |
| South West (England) | -- | -- | -- | 0.0103 |
| Reference region: North East (England) | -- | -- | -- | -- |
| Number of observations | 896 | 931 | 651 | 308 |
| Likelihood ratio test (H0: σu = 0) | 241.3 *** | 372.9 *** | 197.3 *** | 100.3 *** |

Czech Republic, Hungary and Poland, 2004-13

| Variable | Czech Republic | Hungary | Poland |
|---|---|---|---|
| Farm size, hectares of UAA | 0.0000 | -0.00002 | 0.00003 * |
| Total subsidies per output | 0.4039 *** | 0.2719 *** | 0.1173 *** |
| Farmer's age | -0.0017 | 0.0002 | -0.0016 *** |
| Farm organisational form | -- | -- | -- |
| Paid AWU share | -0.0005 | 0.0003 | 0.0006 *** |
| Rented land share | 0.0016 *** | 0.0001 | 0.0001 |
| Investment intensity | -0.0003 ** | 0.00002 | -0.0001 ** |
| Contract use share | 0.0039 ** | -0.0055 *** | -0.0076 *** |
| Crop production diversification index | -0.0059 | 0.0003 | -0.0005 |
| Livestock output share | 0.0009 | -0.0002 | 0.0005 * |
| Other farm output share | 0.0008 | -0.0001 | -0.0023 * |
| Organic farm | 0.0016 | 0.0091 | 0.0665 |
| LFA | -0.0408 ** | 0.0023 | 0.0354 *** |
| Jihozápad | 0.0397 * | -- | -- |
| Severozápad | 0.0254 | -- | -- |
| Severovýchod | 0.0416 | -- | -- |
| Jihovýchod | 0.0145 | -- | -- |
| Střední Morava | -0.0101 | -- | -- |
| Moravskoslezsko | 0.0167 | -- | -- |
| Reference region: Praha | -- | -- | -- |
| Közép-Dunántúl | -- | 0.0240 | -- |
| Nyugat-Dunántúl | -- | 0.0160 | -- |
| Dél-Dunántúl | -- | 0.0441 * | -- |
| Észak-Magyarország | -- | -0.0060 | -- |
| Észak-Alföld | -- | 0.0192 | -- |
| Dél-Alföld | -- | -0.0035 | -- |
| Reference region: Közép-Magyarország | -- | -- | -- |
| Region Południowy | -- | -- | 0.0068 |
| Region Wschodni | -- | -- | -0.0106 |
| Region Północno-Zachodni | -- | -- | -0.0139 |
| Region Południowo-Zachodni | -- | -- | 0.0000 |
| Region Północny | -- | -- | -0.0161 |
| Reference region: Centralny | -- | -- | -- |
| Number of observations | 429 | 538 | 1 119 |
| Likelihood ratio test, H0: σu = 0 | 216.3 *** | 180.3 *** | 249.4 *** |

*Note*: 1. All model variables are the same as in the model specification presented in Table 6 of the report except the subsidy variable, which is measured per 1 Euro of farm output.

***, ** and * - statistically significant at the 1, 5 and 10 percent level, respectively.

**Table B.6. Average marginal effects of selected factors on unconditional expected value of persistent technical inefficiency: Estimates of SF model with heteroscedasticity, specification with coupled and decoupled payments per hectare of UAA 2004-13**

France, Germany and England

| Variable | France[1)] | | Germany | | England |
|---|---|---|---|---|---|
| | Specification 1 | Specification 2 | West Germany | East Germany | |
| Farm size, hectares of UAA | 0.0002 *** | 0.0002 *** | 0.0004 *** | 0.00001 | 0.0001 ** |
| Coupled payments per hectare of UAA | -0.00003 | -- | 0.0002 *** | 0.0003 *** | 0.0005 *** |
| Decoupled payments per hectare of UAA | -- | -0.0001 | -0.0001 | -0.0001 | -0.0001 |
| Farmer's age | -0.00003 | 0.0002 | -0.0015 | -0.0004 | -0.0019 ** |
| Farm organisational form[2)] | -- | -- | 0.0495 *** | -- | 0.0234 |
| Paid AWU share | 0.0005 *** | 0.0005 *** | 0.0006 *** | 0.0003 | -0.0002 |
| Rented land share | -0.0003 ** | -0.0003 ** | 0.0003 | 0.0003 | -0.0001 |
| Investment intensity | -0.0001 | -0.00004 | 0.00002 | -0.0002 ** | -0.00002 |
| Contract use share | -0.0002 | -0.0002 | -0.0013 * | -0.0008 | -0.0011 |
| Crop production diversification index | 0.0049 * | 0.0047 * | 0.0110 *** | -0.0032 | 0.0050 |
| Livestock output share | -0.0009 ** | -0.0009 *** | -0.0002 | -0.0003 | -0.0006 |
| Other farm output share | -0.0043 *** | -0.0042 *** | -0.0006 | 0.0002 | -0.0061 *** |
| Organic farm | 0.1143 * | 0.0931 | 0.0071 | -0.0497 | -0.1465 |
| LFA | 0.0350 *** | 0.0336 *** | 0.0354 *** | 0.0946 *** | 0.0219 |
| Bassin parisien | 0.0115 | 0.0091 | -- | -- | -- |
| Nord-Pas-de-Calais | -0.0267 | -0.0292 | -- | -- | -- |
| Est | -0.0007 | -0.0056 | -- | -- | -- |
| Reference region: Île de France | -- | -- | -- | -- | -- |
| Bayern | -- | -- | 0.0354 *** | -- | -- |
| Hessen | -- | -- | 0.0024 | -- | -- |
| Niedersachsen | -- | -- | -0.0203 | -- | -- |
| Nordrhein-Westfalen | -- | -- | 0.0258 * | -- | -- |
| Rheinland-Pfalz | -- | -- | -0.1322 *** | -- | -- |
| Saarland | -- | -- | 0.0150 | -- | -- |
| Schleswig-Holstein | -- | -- | 0.0609 *** | -- | -- |
| Reference region: Baden-Württemberg | -- | -- | -- | -- | -- |
| Mecklenburg-Vorpommern | -- | -- | -- | 0.0946 *** | -- |
| Sachsen | -- | -- | -- | 0.0088 | -- |
| Sachsen-Anhalt | -- | -- | -- | -0.0045 | -- |
| Thüringen | -- | -- | -- | -0.0053 | -- |
| Reference region: Brandenburg | -- | -- | -- | -- | -- |
| North West (England) | -- | -- | -- | -- | 0.0219 |
| Yorkshire And The Humber | -- | -- | -- | -- | 0.0242 |
| East Midlands (England) | -- | -- | -- | -- | -0.0065 |
| West Midlands (England) | -- | -- | -- | -- | -0.0095 |
| East of England | -- | -- | -- | -- | -0.0316 |
| South East (England) | -- | -- | -- | -- | -0.0118 |
| South West (England) | -- | -- | -- | -- | 0.0095 |
| Reference region: North East (England) | -- | -- | -- | -- | -- |
| Number of observations | 896 | 896 | 931 | 651 | 308 |
| Likelihood ratio test, H0: $\sigma_u = 0$ | 204.2 *** | 209.2 *** | 372.9 *** | 197.3 *** | 94.8 *** |

Czech Republic, Hungary and Poland

| Variable | Czech Republic | | Hungary | | Poland | |
|---|---|---|---|---|---|---|
| Farm size, hectares of UAA | 0.00001 | | -0.00003 | ** | 0.00001 | |
| Coupled payments per hectare of UAA | 0.00005 | | 0.0003 | *** | 0.0001 | *** |
| Decoupled payments per hectare of UAA | 0.00003 | | -0.0006 | ** | 0.0001 | |
| Farmer's age | -0.0019 | ** | 0.0003 | | -0.0016 | *** |
| Farm organisational form | -- | | -- | | -- | |
| Paid AWU share | -0.0007 | | 0.0001 | | 0.0006 | *** |
| Rented land share | 0.0009 | * | 0.0002 | | 0.0002 | |
| Investment intensity | -0.0002 | ** | -0.0001 | | -0.0001 | ** |
| Contract use share | 0.0023 | * | -0.0078 | *** | -0.0062 | *** |
| Crop production diversification index | 0.0090 | *** | 0.0057 | *** | 0.0018 | |
| Livestock output share | -0.0008 | ** | -0.0014 | *** | 0.0001 | |
| Other farm output share | -0.0001 | | -0.0022 | ** | -0.0017 | |
| Organic farm | 0.0074 | | 0.2177 | * | 0.0691 | |
| LFA | -0.0065 | | 0.0212 | | 0.0612 | *** |
| Jihozápad | 0.0313 | * | -- | | -- | |
| Severozápad | 0.0297 | | -- | | -- | |
| Severovýchod | 0.0226 | | -- | | -- | |
| Jihovýchod | -0.0040 | | -- | | -- | |
| Střední Morava | -0.0259 | | -- | | -- | |
| Moravskoslezsko | 0.0049 | | -- | | -- | |
| Reference region: Praha | -- | | -- | | -- | |
| Közép-Dunántúl | -- | | -0.0226 | | -- | |
| Nyugat-Dunántúl | -- | | -0.0110 | | -- | |
| Dél-Dunántúl | -- | | 0.0129 | | -- | |
| Észak-Magyarország | -- | | -0.0199 | | -- | |
| Észak-Alföld | -- | | -0.0100 | | -- | |
| Dél-Alföld | -- | | -0.0090 | | -- | |
| Reference region: Közép-Magyarország | -- | | -- | | -- | |
| Region Południowy | -- | | -- | | 0.0612 | |
| Region Wschodni | -- | | -- | | 0.0085 | |
| Region Północno-Zachodni | -- | | -- | | -0.0019 | |
| Region Południowo-Zachodni | -- | | -- | | -0.0133 | |
| Region Północny | -- | | -- | | 0.0087 | |
| Reference region: Centralny | -- | | -- | | -- | |
| Number of observations | 429 | | 538 | | 1,119 | |
| Likelihood ratio test, H0: $\sigma_u = 0$ | 179.4 | *** | 124.0 | *** | 193.0 | *** |

*Note*: 1. All model variables are the same as in the model specification presented in Table 6 of the report except the subsidy variable. A distinction between coupled and decoupled payments was done here. As coupled and decoupled payments show a strong correlation for French farm sample, their effects were estimated using two separate model specifications.

***, ** and * - statistically significant at the 1, 5 and 10 percent level, respectively.

**Table B.7. Factors of farm flexibility: RE GLS model estimates for selected study countries, 2004-13**

| Variables | Germany | | United Kingdom | Hungary | Poland |
|---|---|---|---|---|---|
| | West Germany | East Germany | | | |
| Farm size, hectares of UAA | 0.0001 *** | -0.0004 *** | -0.0003 *** | -0.0001 *** | -0.0034 *** |
| Decoupled subsidies per hectare of UAA | -0.00001 | -0.0002 ** | -0.00002 | -0.00005 | 0.0001 |
| Farmer's age | -0.0001 | 0.0007 | -0.0001 | 0.00003 | 0.0001 |
| Farm organisational form | -0.0022 | -- | 0.0179 ** | -- | -- |
| Paid AWU share | -0.0002 *** | -0.0005 *** | -0.0001 ** | -0.0002 *** | -0.0002 ** |
| Rented land share | 0.0001 *** | 0.00003 | -0.0001 * | -0.0003 *** | -0.0006 *** |
| Contract use share | -0.0006 *** | -0.0044 *** | 0.0010 *** | 0.0013 *** | 0.0025 *** |
| Crop production diversification index | -0.0003 | 0.0024 | 0.0036 *** | -0.0011 *** | 0.0037 *** |
| Livestock output share | -0.0007 *** | -0.0030 *** | -0.0007 *** | 0.0001 | -0.0010 *** |
| Other farm output share | -0.0008 *** | -0.0053 *** | -0.0014 *** | -0.0010 *** | -0.0003 |
| Organic farm | -0.0155 | 0.0598 | -0.0194 | -0.0288 * | 0.0214 ** |
| LFA | 0.0056 ** | 0.0562 *** | 0.0168 | -0.0008 | 0.0168 *** |
| Protein crops' area share | -0.0005 ** | 0.0007 | 0.0005 ** | 0.0005 | 0.0003 *** |
| Energy crops' area share | -0.0003 ** | -0.0003 | 0.0004 | -0.0003 | 0.0008 ** |
| Intensity of fertiliser and plant protection | -0.0001 *** | 0.0002 *** | -0.00004 ** | 0.0001 *** | -0.0001 *** |
| year 2005 | -0.0047 | 0.0641 * | 0.0135 | -0.0046 | -0.0207 ** |
| year 2006 | -0.0143 ** | 0.0744 ** | 0.0068 | -0.0069 | -0.0361 |
| year 2007 | -0.0235 *** | 0.0903 ** | 0.0113 | 0.0179 *** | -0.0315 |
| year 2008 | -0.0351 *** | 0.0623 | 0.0435 *** | -0.0058 | -0.0219 |
| year 2009 | -0.0398 *** | 0.0166 | 0.0587 *** | -0.0164 * | -0.0272 |
| year 2010 | -0.0506 *** | 0.0307 | 0.0386 *** | -0.0185 * | -0.0687 |
| year 2011 | -0.0610 *** | 0.0708 * | 0.0575 *** | -0.0123 | -0.0323 |
| year 2012 | -0.0693 *** | 0.0154 | 0.0773 *** | -0.0048 | -0.0438 |
| year 2013 | -0.0753 *** | 0.0224 | 0.0985 *** | -0.0123 | -0.0393 |
| Bayern | -0.0084 ** | -- | -- | -- | -- |
| Hessen | 0.0059 | -- | -- | -- | -- |
| Niedersachsen | 0.0067 | -- | -- | -- | -- |
| Nordrhein-Westfalen | 0.0033 | -- | -- | -- | -- |
| Rheinland-Pfalz | 0.0129 *** | -- | -- | -- | -- |
| Saarland | 0.0252 *** | -- | -- | -- | -- |
| Schleswig-Holstein | 0.0145 *** | -- | -- | -- | -- |
| Reference region: Baden-Württemberg | 0.4308 *** | -- | -- | -- | -- |
| Mecklenburg-Vorpommern | -- | 0.0062 | -- | -- | -- |
| Sachsen | -- | -0.0355 | -- | -- | -- |
| Sachsen-Anhalt | -- | 0.0120 | -- | -- | -- |
| Thüringen | -- | -0.0358 | -- | -- | -- |
| Reference region: Brandenburg | -- | 0.6026 *** | -- | -- | -- |

**Table B.7. Factors of farm flexibility: RE GLS model estimates for selected study countries, 2004-13** (*cont.*)

| | | | | | |
|---|---|---|---|---|---|
| North West (England) | -- | -- | 0.0054 | -- | -- |
| Yorkshire And The Humber | -- | -- | 0.0047 | -- | -- |
| East Midlands (England) | -- | -- | 0.0034 | -- | -- |
| West Midlands (England) | -- | -- | -0.0125 | -- | -- |
| East of England | -- | -- | -0.0086 | -- | -- |
| South East (England) | -- | -- | -0.0137 | -- | -- |
| South West (England) | -- | -- | 0.0054 | -- | -- |
| Reference region: North East (England) | -- | -- | 0.3646 *** | -- | -- |
| Közép-Dunántúl | -- | -- | -- | -0.0029 | -- |
| Nyugat-Dunántúl | -- | -- | -- | -0.0036 | -- |
| Dél-Dunántúl | -- | -- | -- | 0.0010 | -- |
| Észak-Magyarország | -- | -- | -- | -0.0050 | -- |
| Észak-Alföld | -- | -- | -- | -0.0093 | -- |
| Dél-Alföld | -- | -- | -- | -0.0156 * | -- |
| Reference region: Közép-Magyarország | -- | -- | -- | 0.2270 *** | -- |
| Region Południowy | -- | -- | -- | -- | -0.0160 |
| Region Wschodni | -- | -- | -- | -- | 0.0197 ** |
| Region Północno-Zachodni | -- | -- | -- | -- | -0.0606 *** |
| Region Południowo-Zachodni | -- | -- | -- | -- | -0.0384 *** |
| Region Północny | -- | -- | -- | -- | -0.0746 *** |
| Reference region: Centralny | -- | -- | -- | -- | 0.7937 *** |
| sigma u | 0.0231 *** | 0.0978 *** | 0.0347 *** | 0.0419 *** | 0.0745 *** |
| sigma e | 0.0376 *** | 0.0650 *** | 0.0355 *** | 0.0374 *** | 0.0406 *** |
| Number of observations | 3582 | 882 | 1279 | 2461 | 5711 |
| R squared | 0.3036 | 0.5624 | 0.4478 | 0.4640 | 0.7395 |
| Wald chi square | 1317.37 (31) | 557.46 (27) | 884.78 (31) | 1014.50 (29) | 4447.52 (28) |

1. Farm organisational form was removed for East Germany, Hungary and Poland to avoid multicollinearity due to high correlation with the share of rented land variable.

**Table B.8. Factors of diseconomies of scope: RE \GLS model estimates for selected study countries, 2004-13**

| Variables | Germany | | Poland |
|---|---|---|---|
| | West Germany | East Germany | |
| Farm size, hectares of UAA | 0.00003 | 0.00001 | 0.0017 *** |
| Decoupled payments per hectare of UAA | 0.0001 ** | 0.0001 ** | -0.00001 * |
| Farmer's age | 0.00004 | -0.0003 | -0.0001 |
| Farm organisational form[1)] | 0.0009 | -- | -- |
| Paid AWU share | 0.0002 ** | 0.0001 ** | 0.0002 *** |
| Rented land share | -0.0002 *** | 0.0001 | 0.0003 *** |
| Contract use share | 0.0006 ** | 0.0018 *** | -0.0013 *** |
| Crop production diversification index | -0.0012 | 0.0032 * | 0.0001 |
| Livestock output share | 0.0008 *** | 0.0004 *** | 0.0007 *** |
| Other farm output share | 0.0010 *** | 0.0021 *** | 0.0002 |
| Organic farm | 0.0172 | 0.0108 | -0.0130 ** |
| LFA | -0.0106 *** | -0.0147 *** | -0.0093 *** |
| Protein crops' area share | 0.0003 | -0.0001 | 0.0001 ** |
| Energy crops' area share | -0.0004 * | 0.0002 | -0.0005 *** |
| Intensity of fertiliser and plant protection use | 0.0001 *** | 0.0001 *** | 0.0001 *** |
| year 2005 | -0.0100 | -0.0294 ** | 0.0079 *** |
| year 2006 | -0.0143 | -0.0372 *** | 0.0143 *** |
| year 2007 | -0.0150 * | -0.0396 *** | 0.0106 *** |
| year 2008 | -0.0043 | -0.0320 ** | 0.0070 *** |
| year 2009 | 0.0025 | -0.0308 ** | 0.0048 ** |
| year 2010 | 0.0101 | -0.0431 *** | 0.0201 *** |
| year 2011 | 0.0196 ** | -0.0464 *** | 0.0010 |
| year 2012 | 0.0365 *** | -0.0453 *** | 0.0038 * |
| year 2013 | 0.0476 *** | -0.0467 *** | 0.0032 |
| Bayern | 0.0013 | -- | -- |
| Hessen | -0.0071 | -- | -- |
| Niedersachsen | -0.0283 *** | -- | -- |
| Nordrhein-Westfalen | 0.0061 | -- | -- |
| Rheinland-Pfalz | -0.0144 ** | -- | -- |
| Saarland | -0.0413 *** | -- | -- |
| Schleswig-Holstein | -0.0222 *** | -- | -- |
| Reference region: Baden-Württemberg | 0.0539 *** | -- | -- |
| Mecklenburg-Vorpommern | -- | -0.0025 | -- |
| Sachsen | -- | 0.0150 * | -- |
| Sachsen-Anhalt | -- | -0.0049 | -- |
| Thüringen | -- | 0.0211 ** | -- |
| Reference region: Brandenburg | -- | 0.2840 *** | -- |
| Region Południowy | -- | -- | 0.0012 |
| Region Wschodni | -- | -- | -0.0110 ** |
| Region Pólnocno-Zachodni | -- | -- | 0.0256 *** |
| Region Południowo-Zachodni | -- | -- | 0.0128 ** |
| Region Pólnocny | -- | -- | 0.0343 *** |
| Reference region: Centralny | -- | -- | 0.1026 *** |
| sigma u | 0.0000 *** | 0.0347 *** | 0.0000 *** |
| sigma e | 0.0000 *** | 0.0224 *** | 0.0000 *** |
| Number of observations | 3978 | 882 | 5711 |
| Log likelihood | 4922.6 | 1832.4 | 11949.4 |
| LR test: sigma u=0 | 303.6 | 386.3 | 2858.9 |

1. Farm organisational form was removed for East Germany and Poland to avoid multicollinearity due to high correlation with the share of rented land variable.