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WORKING PAPER NO. 415

Shadow Prices of Human Capital in Agriculture. Evidence from European FADN Regions

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September 2015

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Shadow Prices of Human Capital in Agriculture. Evidence from European FADN Regions

Biagia De Devitiis* and Ornella Wanda Maietta**

Abstract

The aim of this paper is to measure the shadow price of human capital in EU agriculture and to determine whether the CAP has affected the productivity of this growth-enhancing factor. For this purpose, we used the balance sheet data for the period 1986-2012, referring to the Standard Results of the EU Farm Accountancy Data Network (FADN) farm, which is representative of commercial agriculture at regional level. Data concerning output and input price indices and education attainment levels were obtained from Eurostat and from national FADNs. DEA-VRS input-oriented annual frontiers were computed to estimate the shadow price of three levels of human capital: low, medium and high. The results show an increasing trend in the shadow prices of human capital and suggest that the shadow price of the high level of human capital has been significantly greater than the shadow price of the medium level of human capital since 1990.

Keywords: shadow prices, human capital, agriculture, growth, Malmquist index, DEA.

JEL codes: 047, 015, D24, E24, I26, C43.

Acknowledgements: The authors would like to thank Aldo Vitagliano (CFEPSR, Italy), for organizing the data-set, and the following people for the data they provided: Sergio Destefanis (University of Salerno), Francesco Pecci (University of Verona), Nadia Gargano (CIHEAM-IAMM, Montpellier), Emmanuel Jacquin, Beatriz Velasquez and Anne Waniart (European Commission), Pol Marquer, Denisa Florescu, Johanna Pleijte and Iulia-Paula Pop (Eurostat), Béatrice Sédillot (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, France), Raphaela Ellßel, Heiko Hansen and Werner Kleinhanß, (TI, Germany), Gabor Suga and Keszthelyi Szilárd (Research Institute of Agricultural Economics, Hungary), Stefano Dell'Acqua, Franco Mari and Matteo Martino (INEA, Italy), Piotr Czarnota and Zbigniew Florianczyk (Institute of Agricultural and Food Economics, Poland, Katarina Bradacova and Stefan Buday (National Agricultural and Food Centre, Slovakia) and Lindsey Clothier (DEFRA, UK).

The authors would also like to express their gratitude for the information provided by Josef Hanibal (Research Institute for Agriculture Economics, Czech Republic), Stavroula Ioannou (Agricultural Research Institute, Cyprus), Rima Daunyt (Lithuanian Institute of Agrarian Economics, Lithuania), Sandra Brücher (Ministère de l'Agriculture, de la Viticulture et de la Protection des consommateurs, Luxembourg), Raimundo Fombellida Aragón (Ministerio de Agricultura Alimentación y Medio Ambiente, Spain), Adriana Di Liberto (University of Cagliari), Lennart Hjalmarsson (University of Gothenburg), Petre Badulescu (Linnaeus University) and Dimitris Christellis (CSEF). Finally, the authors wish to express their heartfelt thanks to Marco Pagano (University of Naples Federico II, CSEF and EIEF) for the useful feedback he provided on previous versions of this paper. The usual disclaimer applies.

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1. Introduction

Human capital investment, that is investment in learning new skills, both through traditional schooling and post-school job training, is an important source of productivity gains and long-run economic growth. On the one hand, according to the neoclassical approach (Lucas, 1988; Mankiw *et al*., 1992), human capital is to be considered as an additional input in the production function and the process of economic growth is explained by its accumulation. On the other hand, according to the Schumpeterian approach, growth is explained by the initial endowment of human capital, which influences a country's (or a region's) capability to innovate and to catch up with the technology of the leader area (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994).

Traditionally, research in agricultural economics follows the neoclassical model by estimating an average production function after introducing human capital as a non-conventional factor. Human capital is mainly represented by a measure of schooling and its relevance is measured in terms of output elasticity (Evenson, Kislev, 1975; Nguyen, 1979; Antle, 1983; Kawagoe, Hayami, Ruttan, 1985; Lau, Yotopoulos, 1988, Trueblood, 1991; Mundlak *et al*., 1999; De Devitiis and Maietta, 2009). Griliches (1988) and Rutten (1992) define education as the quality of labour changing over time whose accurate measurement, besides that of other inputs, is essential for measuring Total Factor Productivity (TFP) as a residual. For most of the world's agriculture, TFP growth is no longer a resource-based process, driven by material input accumulation, but a productivity-based process, mainly driven by the accumulation of immaterial inputs – including human capital (Fuglie, 2015).

From a microeconomic perspective, education in agriculture acts as a non-neutral input, which enables highly skilled workers to select the appropriate input bundles and efficiently distribute the inputs among the various competing uses (Welch, 1970). The return to this ability is part of the return to farmers' education. However, in agriculture the incentive of acquiring a college education is based on dynamic considerations of changing technology; if technology becomes stagnant, this incentive is reduced and may even disappear. In applied research, the use of education is widespread, as documented in several reviews on farm efficiency (Lockeed, Jamison, Lau, 1980; Bravo-Ureta, Pinehiero, 1993).

In a globalized knowledge-based and service economy, human capital investment is becoming more and more important, since it is complementary with the acquisition of information and particularly with information technology. At the sector level, an efficient agricultural education system is essential for agriculture to be internationally competitive, as new technologies cannot be imported wholesale and must be adapted to country-specific natural conditions through national education and research (Csaki, 1999).

The private return of human capital investment in agriculture has been influenced by the Common Agricultural Policy (CAP) of the European Union (EU), whose main objective is to reduce regional disparities in agricultural productivity. In the recent Fischer Reform, direct support and structural policies are aimed at achieving competitiveness and a greater market orientation for which corporate efficiency, together with environmental safeguarding, become key issues. Regarding direct support policies, intervention mechanisms play a less important role than in the past and support is mainly decoupled and subject to cross-compliance. Concerning structural interventions, rural development policy has been strengthened with funds and policy instruments aimed at providing environmental goods and diversifying activities in a more targeted and locally tailored manner (Bascou, 2008). At the same time, the history of the CAP has created a culture of “rights to cash support” with little accountability regarding the counterparts in the farm community across Europe (Mahè and Bureau, 2008).

A stronger market-orientation of agricultural policy should foster aggregate productivity gains for the sector as a whole since less profitable farms should close down while high performing farms, able to create an environment that promotes continuous learning and problem, should survive (Kazukauskas *et al.*, 2010, 2013).

The ability to summarize information from various sources and to engage in non-routine problem solving is generally learned at school (Swaim, 1995; Gasson, 1998). Therefore, the demand for higher-order cognitive skills, as represented by the high level of human capital in European agriculture, should be reinforced by the recent CAP. For example, better agricultural education favours participation in agri-environmental schemes, such as those aimed at involving European farmers in biodiversity protection (Dupraz *et al*., 2002).

Notwithstanding the relevance of human capital for farm survival and growth, the link between the CAP reforms and human capital productivity has not been yet investigated. However, the literature has evidenced that decoupling influences productivity growth mainly through increased specialisation in more productive farming activities (Kazukauskas *et al.*, 2014). The issue is relevant since a higher productivity of human capital might attract this input into the sector.

A simple way of testing the hypothesis that the greater CAP market-orientation has impacted human capital productivity, is to determine whether the productivity of the high level of human capital in European agriculture has increased over time by estimating its shadow price.

In economic literature, the computation of shadow prices is a common practice when market prices are inapplicable, unknown or inappropriate, for example when market prices are distorted due to government intervention (Coelli and Prasada Rao, 2005).

The data used for this study were obtained from the Farm Accountancy Data Network (FADN), which was established to evaluate the impact of the CAP on the type of production and income of commercial European agricultural holdings. The only harmonised source for the level of human capital in EU agriculture is the Eurostat Farm Structure Survey (FSS), which periodically measures the percentage of farm holders with practical, basic and full agricultural training.

The main aim of this paper is to measure the productivity of the various levels of human capital for all the years for which information on farm holders' training is available. A second and complementary task is to measure the increase in productivity from 1986 to 2012 by computing a TFP index, or more precisely a Malmquist index, using a non-parametric approach, for a balanced panel of FADN regions.

The remainder of the paper is divided into five sections. The history of the CAP and figure relative to the level of human capital in EU agriculture are reported in section two. Sections three and four focus respectively on the methodology and on the data used. Section five describes the results obtained. Section six provides concluding remarks and the Appendix reports the variables' description, the technical efficiency levels and the TFP rates relative to FADN region and the confidence intervals of the Malmquist index components.

2. The CAP and level of human capital in the EU agriculture

Several and continual changes have been made to the CAP since the 1980s. Production limits have helped to reduce surpluses (milk quotas were first applied in 1984) and much emphasis has been placed on environmentally-sound farming. The first fundamental reform was the McSharry–Reform in 1992 followed by "Agenda 2000" in 1999 and later by the Fischler (or Mid-Term) Reform in 2003. Due to these reforms, the

CAP has focused more and more on R&D programmes and investments in human resources (Fischler, 2008).

The 1992 MacSharry Reform caused a shift from market support to producer support. Cereal intervention prices were scaled down, output payments for oilseeds were eliminated and per hectare compensatory payments, computed on the basis of average regional yield levels, were introduced together with compulsory set-aside requirements attached to these payments.

The 1999 "Agenda 2000" reform further cut intervention prices, bringing them closer to world market levels as well as aligning payments of cereals and oilseeds with the aim of promoting the competitiveness of European agriculture. "Agenda 2000" also initiated the Rural Development policy, a wider structural strategy of decentralised spatial management of rural territories in Member States, aimed at their sustainable development, on the base of the valorisation of both agricultural and non-agricultural activities.

In 2003, the Mid-Term Reform was agreed which promoted sustainability and cohesion: farmers receive a single farm payment per hectare of land calculated by dividing the total payments received over a historical period by the number of hectares of the farm. Premiums, which were earlier related to the number of animals or the size of the milk quota, were added to the flat rate compensation per hectare to a large extent. Single farm payments favour the use of land rather than other inputs in agricultural production and reduce the yields of many commodities; their total output response is less than price support (Sckokai and Anton, 2005). Furthermore, they severed the link to production. It was decided to decouple subsidies from production in order to orient farmers towards the market since farmers were free to produce what was most profitable for them as land was maintained for agricultural use, while still enjoying a required stability of income. This stability could be rationalised as a compensation for higher production standards with regard to consumer protection, animal welfare and environmental conservation (compared to many non-European countries) since whoever failed to fulfil this 'cross-compliance' condition risked reductions in the direct income payment (Moro and Sckokai, 2013). The reform was in effect from 2005 onwards (Kazukauskas *et al.*, 2013).

Farmers' and extension service operators' surveys underline that the new market-orientation of the European agricultural production, fostered by the Mid-Term Reform, requested new professional competences for both. The background of the extension services operators was particularly agronomic and not business management-oriented (Vagnozzi, 2007; Se.Ri.Fo, 2010).

Table 1 reports the arithmetic average of farmers with full agricultural training, calculated according to FADN regions, and the arithmetic average of the percentage of population aged from 15 to 64 years with tertiary education, calculated from Eurostat national data.

Table 1 - The level of human capital in EU agriculture and economy in 2010

Aggregate	**% farmers with full agricultural training**	**% population with tertiary education**
EU-6	14.9	25.1
EU-9	14.4	26.9
EU-10	13.6	26.2
EU-12	12.0	25.3
EU-15	12.3	25.4
EU-25	12.6	23.7
EU-27	11.3	23.1

Source: Our own elaborations on Eurostat data

Even though educational attainment is a poor indicator of the extent to which individuals possess the cognitive skills and technical knowledge required when carrying out more demanding and better-paid jobs, the table underlines the evident gap between rural and urban educational levels (Swaim, 1995). However, while the arithmetic average of the percentage of population with tertiary qualifications is not appreciably sensitive to the EU aggregate, the arithmetic average of the percentages of farmers with full agricultural training seems to decrease with the subsequent EU enlargements. The regions of the Founding Member States have on average the highest level of human capital. Italy is the only exception, as you can see from Figure 1.

Figure 1 reports the percentage of farm holders with full agricultural training according to FADN region, which is our proxy of high human capital, in 2010 as computed from FSS data: it ranges from 0.2% in Ipiros-Peloponissos-Nissi Ioniou to 45.9% in Latvia and Luxembourg.

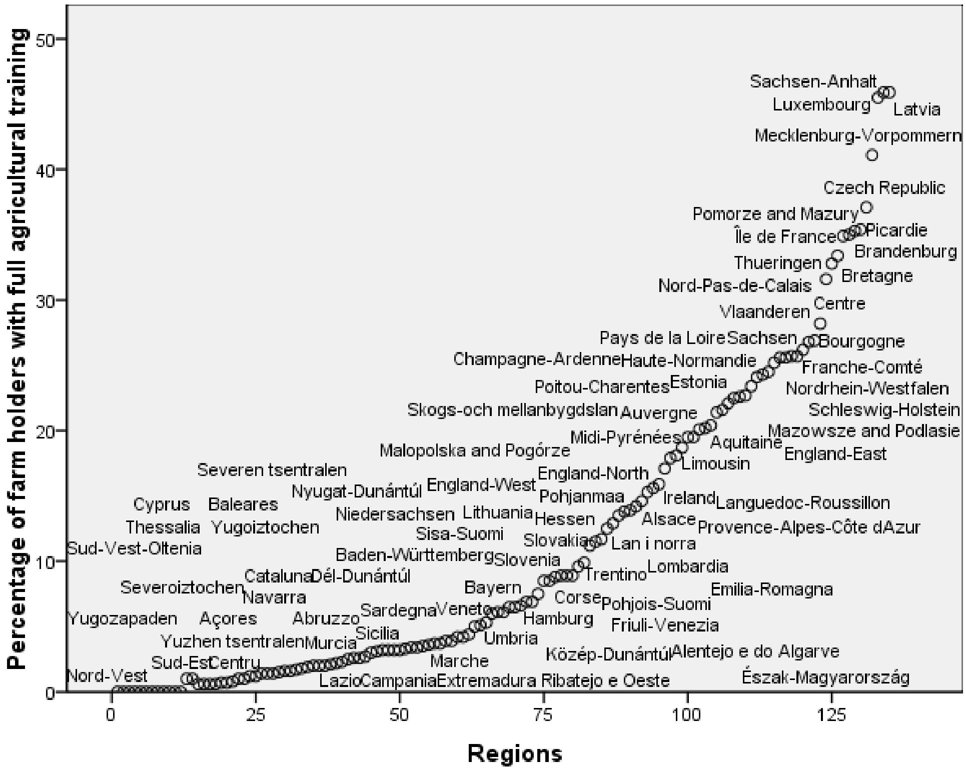

Figure 1 - The percentage of farm holders with full agricultural training according to FADN region in 2010 (our elaboration on Eurostat FSS data)

The percentage of farmers with full agricultural training is not completely comparable between regions since both the national agricultural education systems and the higher education policies for regional development differ greatly (Batterbury and Hill, 2003). Furthermore, the FSS indicator of high human capital in agriculture is tailored for countries such as France and Germany, which have a practical, agricultural college-based school programme for whoever intends to become a farm manager. In Italy, where there is no system of this kind, the percentage of farm holders with agricultural college-bachelor qualification only amounts to 12% of the total number of farm holders with bachelor qualifications in 2010 (De Devitiis and Maietta, 2012). On the other hand, the curricula of the agricultural colleges may be focused on skills that European farmers consider to be too technical and poor on business management and entrepreneurship and therefore unsuitable for training successful modern agribusiness managers who have to compete in an increasingly liberalised system of world trade (Harrison Mayfield and Errington, 1994; Se.Ri.Fo, 2010). A second explanation for the significant differences observed in the level of high human capital across the EU regions is the effect of the different European agricultural structures and farm size distributions which still exist after almost 50 years of

CAP (Haniotis, 2008). Large farms are more likely to be endowed with high levels of farmer human capital but also, in a strongly polarized farm size distribution, any increase in the level of human capital in the relatively few professional farms is camouflaged by the absence of increase or by the low increase in the level of human capital on the more numerous smaller farms.

3. The Methodology

3.1 Shadow prices and technical efficiency

Shadow prices are prices that make the observed quantities optimal. Their estimation, through the linear programming or the econometric approach, is common in economic literature. This may be the case of both consumption analyses and production studies. Limiting to the applications of the non-parametric approach, shadow prices of nutrients can be cited as examples of consumption analysis (Athanasios *et al*., 1994; Håkansson, 2015), while examples of production studies include the shadow prices of biodiversity (Bostian and Herlihy, 2014; Färe *et al*., 2001; Sipilainen and Huhtala, 2013), volunteers' work (Destefanis and Maietta, 2009), hospital outputs (O'Donnell and Nguyen, 2013), water and wind resources (Ilak *et al*., 2015) and undesirable outputs (Leleu, 2013; Boussemart *et al*., 2015).

For measuring productivity, shadow prices are estimated in order to overcome the lack of market price or can be used as appropriate indicators of input productivities. With the aim of carrying out inter-country comparisons of agricultural productivity, Coelli and Rao (2005) and Nin-Pratt and Yu (2010) estimated shadow input prices in order to obtain shadow input cost shares which are required for aggregating input accumulation and measuring agricultural TFP. Ten Raa and Mohnen (2002) used shadow input prices as a valuation of input productivities, which are not affected by variations of the economy in market power, disequilibrium in factor holding, suboptimal capacity utilization and returns to scale. The shadow input prices are then used to aggregate input accumulation and measure TFP.

The computation of shadow prices may provide values equal to zero[2] for some inputs.

[2] Relative to buildings, equipment, land and infrastructure in Ten Raa and Mohnen (2002) and Coelli and Rao (2005).

When selecting the optimal production plan through linear programming, input shadow prices are null in case of free good (Paris, 1991) that is firm supply of the *kth* input is strictly greater than firm demand for that input, while the input shadow price is positive when firm demand of that input is equal to its supply. It is also possible to have a zero shadow price together with the demand for the input, which is equal to the corresponding supply. This is the case of primal degeneracy whose economic interpretation is the possibility of multiple shadow input price systems. This occurs when three or more resource constraints cross at the same point, corresponding to the optimal production plan. Analogously, in the case of outputs, the shadow price is positive when the marginal cost is equal to the corresponding marginal revenue, while it is null when the marginal cost is greater than the corresponding marginal revenue. It is also possible to have a zero shadow price when the marginal cost is equal to the corresponding marginal revenue. This is the case of dual degeneracy often observed in mathematical programming models. Some activities that are not incorporated in the optimal mix may have the same index of profitability as that of the activities included in the production plan. The reason why the activity is not included in the optimal plan is due to the exhaustion of the available resources required for the activities already in the plan but an alternative plan, which produces the same level of profit as the original plan, is feasible. Therefore degeneracy, corresponds to the existence of multiple optimal solutions and multiple shadow prices.

Within a non-parametric frontier production function framework, the shadow prices are endogenously determined by multiplier or dual linear programming problems since they are the multipliers revealed by individual producers in an effort to maximise their relative efficiency (Fried *et al*., 2008).

More in detail, the frontier approach defines the frontier by using linear combinations of multiple outputs of efficient farms in the *output-oriented* analysis, or of multiple inputs, in the *input-oriented* analysis. The frontier approach emphasises the joint nature of outputs and inputs and concerns various input/output combinations as alternative activities (Jonasson and Apland, 1997). With respect to the frontier deterministic approach, known as the Data Envelopment Analysis (DEA) proposed by Banker, Charnes and Cooper, (1984), the primal (or envelopment) linear programming problem BCC_p-I (BCC_E-I) in its *input-oriented* version, may be expressed as follows:

$$
\begin{aligned}
&\text{BCC}_p\text{-I } (\mathbf{x}_i, \mathbf{y}_i):\\
&\min_{\lambda_i, \gamma_j} \quad \lambda_i\\
&\text{s.t.}\\
&\mathbf{y}_{mi} \le \sum_j \gamma_j \ \mathbf{y}_{mj}, \qquad m = 1, ..., M\\
&\lambda_i \mathbf{x}_{ki} \ge \sum_j \gamma_j \ \mathbf{x}_{kj}, \qquad k = 1, ..., K\\
&\lambda_i \ge 0, \quad \sum_j \gamma_j = 1, \quad j = 1, ..., N
\end{aligned} \tag{1}
$$

where **x** is the input vector, **y** the output vectors, M the number of outputs, K the number of inputs, N the number of firms, *i* is the firm index, λ_i is the *input-oriented* technical efficiency measurement which ranges between 0 and 1, and γ_j are the weights applied to the peer *j* activities in order to describe the optimal production plan for firm i.

In the dual or multiplier model BCC_D^I (o BCC_M-I):

$$
\begin{aligned}
&\text{BCC}_D^I (\mathbf{x}_i, \mathbf{y}_i):\\
&\max_{\mu_i, \nu_i, \omega_i} \quad \mu_i \mathbf{y}_i + \omega_i\\
&\nu_i \mathbf{x}_i = \mathbf{1}\\
&\mu_i \mathbf{y}_i - \nu_i \mathbf{x}_i + \omega_i \le 0\\
&\mu_i \ge 0, \nu_i \ge 0
\end{aligned} \tag{2}
$$

ν_i and μ_i are the shadow prices or multiplier of inputs and outputs respectively while ω_i is an indicator of firm returns to scale.

The existence of slacks in an output or in an input generally corresponds to zero multiplier for that output or that input, however zero weights in the multiplier model do not necessary lead to nonzero slacks, since some slacks may be basic but equal to zero (degenerate solution). Non-unique weights mean that several facets may span an efficient corner point (Thanassoulis and Portela, 2008).

In a cross-country multilateral productivity comparison, the analysis is usually *output-oriented* yet the *input-orientation* is also adopted[3]. Furthermore, when the summary data are expressed on "an average per farm" basis (as in this study), it is sensible to assume

[3] Arnade (1994) applies an input-oriented DEA model to data referring to 77 countries from 1961 to 1987.

a Variable Returns to Scale (VRS) technology since the scale economies of the "average farm" could be discussed (Coelli and Prasada Rao, 2005).

3.2. The Malmquist Index

The Malmquist (1953) index has become popular for making inter-country comparisons of productivity growth. It decomposes productivity growth into a movement of a country toward the frontier plus technical progress.

In order to measure productivity change between periods *t* and *t+1,* we assume that the producible-output at period *t* set is $S^t(x)$ and the *output-oriented* distance function for period *t*, as defined by (Shephard, 1970):

$$D_o^t(\mathbf{x}^t, \mathbf{y}^t) = inf\left\{\delta : \left(\frac{\mathbf{y}^t}{\delta}\right) \in S^t(\mathbf{x}^t)\right\} \leq 1 \quad \forall\, \mathbf{y}^t \in S^t(\mathbf{x}^t) \text{ and } \forall\, \mathbf{x}^t \in R_+^k \quad (3)$$

is a measure of technology efficiency while the mixed-distance function:

$$D_o^{t+1}(\mathbf{x}^t, \mathbf{y}^t) = \inf\left\{\delta : \left(\frac{\mathbf{y}^t}{\delta}\right) \in S^{t+1}(\mathbf{x}^t)\right\} \quad (4)$$

measures the distance from the country's position in the input-output space at time *t* to the boundary of the production set at time *t+1*, where inputs remain constant. It can be higher, lower or equal to 1.

Based on Färe *et al*. (1994) and assuming constant returns to scale, total factor productivity is represented by a generalized *output-oriented* Malmquist index defined as the product of efficiency change (ΔE) and technical progress (*TP*):

$$MI_o = \Delta E * TP \quad (5)$$

$$\Delta E = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad (6)$$

The relative efficiency index is defined by the ratio of technical efficiency at time *t* and time *t+1* and is a measure of a country reaching a frontier representing best-practice technology while the technical progress component, which measures the shifts in the frontier itself, is a geometric mean of two mixed-distance functions for *t* and *t+1* as defined by:

$$TP = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \quad (7)$$

If $MI_o > 1$, there has been positive total factor productivity change between periods. If $MI_o < 1$, then there have been negative changes in total factor productivity. $MI_o = 1$ indicates no change in productivity (Caves *et al*., 1982).

Assuming that the technology exhibits variable returns to scale, and defining $D_o^{t,CRS}$ and $D_o^{t+1,CRS}$ as the two distance functions from the country's position in the input-output space to the boundary of the production set which exhibits constant return to scale, Simar and Wilson (1998) proposed the following decomposition:

$$MI_O = \frac{D_o^{t+1,VRS}(x^{t+1}, y^{t+1})}{D_o^{t,VRS}(x^t, y^t)} \times \frac{D_o^{t+1,CRS}(x^{t+1}, y^{t+1}) / D_o^{t+1,VRS}(x^{t+1}, y^{t+1})}{D_o^{t,CRS}(x^t, y^t) / D_o^{t,VRS}(x^t, y^t)} \times$$
$$\left[\left(\frac{D_o^{t+1,VRS}(x^t, y^t)}{D_o^{t+1,VRS}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^{t,VRS}(x^t, y^t)}{D_o^{t,VRS}(x^{t+1}, y^{t+1})}\right)\right]^{1/2} \times$$
$$\left[\left(\frac{D_o^{t+1,CRS}(x^t, y^t)/D_o^{t+1,VRS}(x^t, y^t)}{D_o^{t+1,CRS}(x^{t+1}, y^{t+1})/D_o^{t+1,VRS}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^{t,CRS}(x^t, y^t)/D_o^{t,VRS}(x^t, y^t)}{D_o^{t,CRS}(x^{t+1}, y^{t+1})/D_o^{t,VRS}(x^{t+1}, y^{t+1})}\right)\right]^{1/2}$$

(8)

where the first term is technical efficiency change *ΔE*, the second term measures changes in the scale of technology, *ΔScale*, the third term (the first one in squared brackets) is pure technical progress, *TP*, and the last term, *ΔShape*, provides information regarding the shape of the technology by describing the change in returns to scale of the VRS technology estimate at two fixed points, which are the country's locations at times *t* and *t+1*. When it is greater than unity, it is a sign that the technology is moving farther from constant returns to scale and is becoming more and more convex. When this index is less than unity, the technology is moving toward constant returns to scale, while there are no changes in the shape of the technology when it is equal to unity.

Confidence intervals for the Malmquist index and its components can be estimated by means of bootstrap, as described by Simar and Wilson (1999).

4. The data

The Council Regulation No. 79/65/*EEC* established the legal basis of FADN which is a European system of sample surveys which are carried out each year and collect structural and accountancy data relating to farms in order to monitor the income and business activities of agricultural holdings. Based on national surveys carried out by the EU Member States, FADN is the only source of harmonised micro-economic data (the bookkeeping principles are the same in all Member States) and is representative of the commercial agricultural holdings in the Union.

Bearing in mind the EU universe of farms[4] used for the FSS, holdings are selected to take part in the annual survey on the basis of sampling plans established at the level of each region in the Union by following the European Commission guidelines provided to the Member States' Liaison Agencies. The survey only covers "commercial" agricultural holdings that is farms exceeding a minimum economic size so as to cover the most relevant parts of agricultural production in each EU Member State. A commercial farm is defined as a farm that is large enough to be the main activity of a farmer and provide him/her with a sufficient level of income to support his or her family. The threshold of the economic size varies across countries, which allows for classification of farms as country-specific commercial holdings.

According to the EU FADN methodology, three dimensions, namely territorial location, economic size and type of farming, are used as stratification variables; territorial location corresponds to FADN regions, which are not necessarily NUT2 regions.

Aggregated data can be downloaded from the Standard Results[5] of the EU-FADN database. The Standard Results refer to the balance sheet of an average farm that is representative of the regional commercial agriculture. A representative farm at regional

[4] The EU universe of farms is the set of farms in the European Union with at least 1 hectare of land and those with less than 1 hectare that provide the market with a certain proportion of their output or produce more than a specified amount of output.
[5] http://ec.europa.eu/agriculture/ricaprod/database/consult_std_reports_en.cfm

level is commonly used in sector models based on linear programming (Jonasson and Jeffrey, 1997). For the purpose of this study, the version A1 report of EU-FADN Standard Results was downloaded for the period from1989 to 2012 while INEA provided the same version with 34 variables for the period from 1986 to 1988[6] (Dell'Acqua, 1995).

The variables' definition is reported in the Appendix.

The specification of the production set used for computing the Malmquist index differs from that used for the shadow prices.

For the former, subsidies and human capital variables were not used, the analysis is *output-oriented* and labour is measured in units as is common practice for measuring agricultural growth; furthermore, only the EU-12 regions were considered in order to obtain balanced panel data.

For the latter, subsidies are added to output. There is much debate in literature on whether subsidies have to be modelled as outputs or inputs: Sipiläinen and Kumbhakar (2010) model subsidies as non-neutral inputs since they affect output both directly and indirectly via inputs and technical change. Bezlepkina *et al*. (2005) model subsidies as second-stage revenues (and hence outputs) since they assume a two-stage decision process; in the first stage subsidies are coupled, assuming that producers account for subsidies when making decisions concerning production, and in the second stage they maximize the overall profit that consists in a sum of first-stage profit and subsidies. In cases of this kind Simar (1998) suggests modelling the variable as an input if it leads to efficiency and as an output if it is detrimental to efficiency. The effect of subsidies on efficiency can also be ambiguous. For the purpose of this paper, subsidies were modelled as outputs since they were coupled for a very long period (Haniotis, 2008) and then acted as higher output prices; later even the recent single farm payment policy was not fully decoupled as the wealth and investment effects of the income transfer positively affect output (Sckokai and Moro, 2009).

For computing shadow prices, an input-orientation is deemed to be more appropriate for evaluating the productivity of the various levels of human capital in terms of the latest CAP objectives that do not encourage input intensification. The human capital variables, which are only present in the computation of shadow prices, were modelled as non-discretionary inputs (that is fixed inputs).

Table 2 reports the descriptive statistics of the variables.

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[6] RICA RI/CC/882 rev. 3

Table 2 - Descriptive statistics of the variables

Variable	Meas. Unit	Average	St. Dev.	Minimum	Maximium
Output	2005-€	87,358	103,424	4,806	948,056
Subsidies	"	15,665	26,882	0	238,769
Materials	"	56,674	75,052	1,894	659,560
Capital	"	29,3228	263,265	8,211	2095,475
Paid labour	AWU*	0.59	1.37	0	15.99
Adjusted paid labour**	Units	0.62	1.48	0	15.72
Low HK	FWU*	0.81	0.38	0	1.94
Medium HK	"	0.19	0.20	0	1.17
High HK	"	0.22	0.34	0	1.92

*FWU (Family Working Units) and AWU (Annual Working Units) are defined as 2,200 hours worked annually

** Adjusted paid labour units are defined as the amount paid for wages divided by a national wage

5. The results

5.1 Technical efficiency and the Malmquist index

The first step is to estimate the annual production function frontiers, with an *output-oriented* DEA-V on the balanced panel data of 88 EU-12 regions for the period 1986-2012, in the specification without human capital variables. The results show that the FADN regions on the frontier are: Champagne-Ardenne and the Netherlands followed by Denmark and Picardie. There has been a reduction in efficiency in Eastern England over the last few years. Technology always shows increasing returns to scale.

On observing Figure 2, it is evident that the average level of *output-increasing* technical efficiency decreases in the years of the reforms that is in 1992, 1999 and 2007, since decoupled payments only fully replaced direct aids only at that time (Haniotis, 2008). The details for each region are reported in the Appendix in Table A.1.

Figure 2 – The average level of *output-increasing* technical efficiency in EU-12

From the computation of the *output-increasing* Malmquist index, it emerges that the productivity growth rate in EU-12 during the period 1986-2012 is, on average, equal to 1.2% mainly due to technical progress whose annual average rate is equal to 1.4%. There was little change in efficiency change and scale variation was even less. As in the past (Bernini Carri, 1995), Denmark reported the highest increase in productivity (with an annual average growth rate equal to 4.7% and an annual average technical progress rate equal to 4.4%). At national level, the Netherlands and France followed with the highest TFP rate, as observed for similar periods in other studies (Coelli and Prasada Rao, 2005). Table 3 reports the annual average for each component of the index. Technical progress decreases following the reform years and the introduction of the Euro currency (2002).

The details for each region are reported in Table A.2 while Table A.3 presents the confidence intervals at 5% level of significance for each component of the index: the average annual productivity growth rate in EU-12 ranges from 1.0% to 1.5% while the average annual technical progress rate ranges from 0.8% to 1.7%. The unreported and unavailable values are those that are not computable with FEAR version 2 software.

Table 3 - Malmquist Index decomposition by year

Year	*MIo*	*ΔET*	*TP*	*ΔScale*	*ΔShape*
1987	1.04	1.05	0.99	1.01	1.00
1988	1.01	1.00	1.02	1.00	1.00
1989	1.00	0.98	1.04	0.99	1.01
1990	1.00	1.00	1.00	1.00	1.00
1991	1.02	1.03	0.99	1.00	0.99
1992	1.05	0.94	1.09	0.96	1.07
1993	1.00	1.09	**0.95**	1.08	0.94
1994	0.99	1.00	1.01	1.00	0.99
1995	0.98	1.03	0.96	1.01	1.00
1996	1.02	1.02	1.01	1.00	1.01
1997	1.03	0.99	1.03	1.00	1.01
1998	1.01	0.94	1.10	0.93	1.06
1999	1.03	1.00	1.03	1.02	0.99
2000	1.03	1.12	**0.93**	1.04	0.98
2001	0.99	1.00	0.99	1.02	0.99
2002	1.07	0.99	1.14	0.96	1.00
2003	0.96	1.02	**0.94**	1.01	1.00
2004	1.05	0.95	1.10	0.94	1.06
2005	1.02	1.05	0.98	1.08	0.96
2006	1.02	0.99	1.03	0.98	1.01
2007	1.04	0.96	1.08	0.98	1.03
2008	1.01	1.03	**0.97**	1.07	0.96
2009	1.03	1.02	1.02	1.01	0.98
2010	1.00	0.98	1.06	0.98	1.00
2011	0.99	1.05	0.95	1.04	0.98
2012	0.98	1.01	0.96	1.01	1.00

5.2 The shadow prices of human capital

Table 4 reports the average shadow prices of different levels of human capital, relative to the average shadow prices of paid labour, that is the marginal rate of substitution between paid labour and the low, medium and high levels of human capital respectively. Frisch software was used for the computation of the shadow prices. The averages were computed including all regions including those for which the shadow prices are null.

Table 4 - Relative shadow prices of human capital by year

Year	No regions	Family labour unit			Family labour unit		
		low	**medium**	**high**	**low**	**medium**	**high**
		not adjusted AWU hours			***adjusted AWU unit***		
1986	76	0.53	2.12	2.24	0.63	1.56	2.14
1990	86	**0.16**	**1.55**	**2.69**	**0.20**	**1.34**	**2.16**
1993	68	0.13	0.48	1.25	0.19	1.26	1.99
1995	71	0.14	0.97	0.89	0.17	1.30	1.49
1997	70	0.08	0.74	5.92	0.14	1.07	1.80
2000	97	**0.23**	**2.10**	**2.82**	**0.24**	**1.71**	**2.46**
2003*	38	0.18	0.67	4.18	0.19	0.45	3.61
2005	121	**0.52**	**1.37**	**3.49**	**0.36**	**1.25**	**2.71**
2006*	38	0.38	0.56	7.19	0.46	0.61	7.41
2010	135	**1.13**	**2.59**	**4.61**	**1.19**	**2.00**	**3.27**

* only Italian and Spanish regions

With respect to the figures in bold, which are more robust because derived from more numerous samples, in all the specifications increases are observed in the relative shadow prices of the three levels of human capital. However, only in 2010 the productivity of the low level of human capital is higher than that of paid labour that was used as a benchmark. The productivity of the medium level of human capital in 2010 is more than twice that of paid labour showing a u-shaped trend, which first decreases and then goes up. Lastly, the productivity of the high level of human capital has been higher than the shadow price of the medium level of human capital since 1990. No significant difference was noticed in the first year: this result may be explained by observing that market support by means of higher than world market prices, does not appear to lead to the development of highly professional skills.

It is important to note that in the period under study the level of human capital increased since the percentages of farm holders with medium and high levels of human capital in EU-12 were respectively equal to 12% and 7% and, in 2010, to 20% and 12% according to FSS data (to 36% and 13%, according to FADN data in 1990). For EU-27, the two percentages are lower in 2010: 18% and 11% according to FSS data (33% and 14% according to FADN data).

Given the assumption of a convex inputs' set any increase in human capital should lower productivity. This assumption could help to explain the increase in productivity of the low level of human capital that was on average equal to 81% of total family labour in 1990 and 53% in 2010. A further explanation is the effect of the various technologies of the new Member States with a past experience of communist economy, where low levels of human capital in agriculture could be associated with larger farms (Pietrzykowski, 2003). Moreover, it could be the effect of the higher market-orientation, pursued by the CAP, since the shadow prices of the low level of human capital are measured relatively to the shadow price of paid labour.

Of course, productivity growth, particularly technical progress as emphasized in the Appendix, and structural change also contributed to the general increase of human capital productivities: according to the FSS data from 1990 to 2007 the average EU-12 farm size increased from 15.6 to 25.3 ha. On the other hand, no significant changes were observed concerning the average age of the farm holders over the years and the EU aggregates.

The computation of shadow prices, based on adjusted AWU unit data, gives the same results in terms of trends but reports a lower increase for the medium and high levels of human capital.

6. Concluding remarks

This paper inquires whether stronger market-orientation in the CAP has impacted human capital productivity. The issue is relevant for agricultural growth since TFP growth in world's agriculture is nowadays driven by human capital and other immaterial inputs. The CAP reform for years 2014-2020, inspired by the need for improving the effectiveness of public resources, is likely to strengthen the relevance of human capital for farm growth.

The aim of the study is pursued by measuring the shadow price of three levels (low, medium and high) of human capital in EU agriculture and to determine which shadow price showed a higher increase compared to the others and to the shadow price of paid labour which was used as benchmark.

By applying the *input-oriented* DEA-VRS approach to the data obtained from the Standard Results of the EU-FADN, an increasing trend was observed for all three levels. The relative shadow prices of the low and high levels of human capital doubled from 1986 to 2010; however, the former was initially very low and only in 2010 the productivity of the low level of human capital exceeded that of paid labour. A smaller increase of shadow price was observed for the medium level of human capital, however, in 2010 its productivity was more than twice that of paid labour. Lastly, the relative shadow price of the high level of human capital was always greater than that of the medium level of human capital and was four times more than that of paid labour in 2010.

These trends could be deemed to be effects of productivity growth (with an annual average rate equal to 1.2% for EU-12), particularly due to technical progress (with an annual average rate equal to 1.4% for EU-12), and of the structural changes stimulated by the CAP. More generally, the trends described are consistent with a higher market-orientation of farmers, as well as a production objective aimed at input-saving given the output level.

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Appendix

A.1. The definition of the variables

Output is the variable *Total output*, code SE131 of EU-FADN balance sheet data, which is the total output of crops and crop products, livestock and livestock products and other products defined by sales and the use of (crop and livestock) products and livestock plus change in stocks of (crop and livestock) products, change in valuation of livestock, various non-exceptional products minus purchases of livestock.

Materials is the variable *Total intermediate consumption*, code SE275 defined as Total specific costs (including inputs produced on the holding) and overheads arising from production in the accounting year.

Capital is *Total assets*, code SE436. It corresponds to the closing value of fixed assets (land, permanent crops, quotas, buildings, machinery, breeding livestock) and current assets (non breeding livestock, stocks of agricultural products and other circulating capital).

Subsidies are the variable *Total subsidies – excluding on investments*, code SE605, which only includes subsidies on current operations linked to production.

In EU-FADN, paid and unpaid labour are defined by the annual timework devoted to work on the holding, which includes all manual, administrative, executive and supervisory activities concerning production on the holding. It excludes labour used under contract and labour used in the production, replacement or major repair of fixed assets.

For family labour, the variables provided are the following: *Unpaid labour input*, code SE015, which refers generally to family labour expressed in Family Work Units (abbreviated as FWU) and *Time worked in hours by unpaid labour input on holding*, code SE016. Analogously, two variables are provided for paid labour: *Paid labour input*, expressed in Annual Work Units (abbreviated as AWU), code SE020 and *Time worked in hours by paid labour input on holding*, code SE021. However, the definitions of FWU and AWU vary across regions, nations and years and between FWU and AWU. "One AWU is equivalent to one person working full-time on the holding. A single person cannot exceed 1 AWU equivalent, even if his actual working time exceeds the norm for the region and type of holding. For persons employed for less than the whole year on the holding, the fraction of AWU is calculated as: Hours worked/Hours per AWU for the region/type of holding" (European Commission, 2008)[7].

Consequently, both hours of family and paid labour were used in this paper; whenever necessary, the definition of a working unit which is adopted, is 2,200 hours worked annually. The use of hours worked implies the assumption of labour divisibility. On the other hand, the Council Regulation No 797/85 on improving the efficiency of agricultural structures (OJ 1985 L 93) establishes that the definition of "farmer practising farming as his main occupation", in the case of a natural person, includes the condition that the time spent on work unconnected with the holding must be less than half of the farmer's total working time (and that the proportion of income deriving from the agricultural holding must be 50% or more of the farmer's total income).

Input quality is usually monitored when measuring productivity (Fuglie, 2015); in particular paid labour productivity may sharply differ according to educational and skill levels (Berde and Piros, 2006). In order to take these differences into account, a further series of paid labour units, adjusted for quality, is computed by dividing the variable *Wages paid*, code SE370, by an estimated national agricultural wage. The national wage was computed using *Cambridge Econometrics* data as the arithmetic average between the compensation per employee and the unitary remuneration in agriculture.

The 2005-based price indices were sourced from Eurostat, and are respectively those for *Agricultural Goods Output*, *Goods and service currently consumed in agriculture* (Input 1) and *Goods and services contributing to agricultural investment* (Input 2). 2000-based price indices were provided by the European Commission for the period between 1986 and 2007.

The level of human capital was sourced from the FSS and was obtained from Eurostat. The FSS referring to 1986 divides farm holders according to primary, secondary and higher managerial agricultural training, later the training types were based on practical experience, basic agricultural training and full agricultural training. The data are relative to NUTS2 regions that do not necessarily correspond to FADN regions, the correspondence between NUTS2 and FADN regions were determined according to the amount of utilised

[7] The definition of annual work unit derives from the FSS. It corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis. Full-time means the minimum hours required by the relevant national provisions governing contracts of employment. If the national provisions do not indicate the number of hours, then 1,800 hours are taken to be the minimum annual working hours: equivalent to 225 working days of eight hours each. FWU and AWU were initially equal to 2,300 hours (de Stefano, 1988); from 1990 up to 2000, they were equal to 2,200 hours; from 2001, the AWU is equal to 1,800 hours whereas the FWU remains equal to 2,200 hours (INEA, multiple years).

agricultural land[8]. The levels of low, medium and high human capital were then computed as the percentages of managers belonging to the corresponding training class. These percentages were used to divide the family labour hours into the three categories of low, medium and high human capital.

The FADN's field of observation, which only includes farms deemed to be commercial, is smaller than the EU universe: in 1985, it ranged from a minimum of 54% of farms covered in Italy to 79% in Denmark with an EU-10 average equal to 57% (Abitabile, 1994). In 2007, the FADN coverage, in comparison with the FSS 2005, ranged from a minimum of 5% of farms covered in Slovakia to 77% in Denmark with an EU-25 average equal to 45% (European Commission, 2010).

Since the FADN universe is smaller than the EU universe, this procedure may cause some statistical biases. However, some national FADNs have recently and autonomously[9] started to collect more details concerning the training of farm holders. The Member States whose Liaison Agencies provided us with these data are: France, Germany, Hungary, Italy, Poland, Slovakia (the percentages of training classes held in 2013 were considered) and UK (only for England). Consequently, only data on the training of farm holders for 2010 collected by the national FADNs were used for 71 regions while FSS data were used for the rest.

Finally, only for Italian and Spanish regions in 2003 and 2006, the educational attainment of farm holders referred to the percentages of farm holders with primary, secondary and tertiary educational level. For Spain this information was downloaded from Instituto Valenciano de Investigaciones Económicas[10] (Di Liberto, 2007) while the information concerning Italy was obtained from Destefanis and Sena (2005) and Costantini and Destefanis (2009), whose interpolation is described in Destefanis *et al.* (2004).

[8] This information was provided by Francesco Pecci (University of Verona).
[9] The European Commission has started to collect data on farm holders' education in 2014.
[10] http://www.ivie.es/

Table A.1 - *Output-increasing* TE by year and by FADN region

FADN region	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
(010) Schleswig-Holstein	0.79	0.71	0.73	0.77	0.74	0.76	0.79	0.84	0.83	0.79	0.80	0.81	0.81	0.80	0.99	0.91	0.91	0.91	0.91	0.99	0.84	0.78	0.76	0.93	0.85	0.81	0.86
(020) Hamburg	0.76	0.83	0.85	0.75	0.83	1	0.84	1	0.92	0.86	0.89	0.85	0.80	0.95	0.93	0.88	0.80	0.93	0.80	0.83	0.82	0.78	0.81	1	0.87	0.78	0.95
(030) Niedersachsen	0.77	0.73	0.74	0.71	0.76	0.83	0.74	0.76	0.77	0.79	0.84	0.82	0.81	0.92	0.99	0.96	0.82	0.90	0.82	0.89	0.85	0.79	0.77	0.94	0.84	0.83	0.86
(050) Nordrhein-Westfalen	0.85	0.79	0.76	0.72	0.73	0.77	0.73	0.78	0.77	0.75	0.81	0.78	0.76	0.88	0.98	0.88	0.85	0.90	0.87	0.91	0.84	0.76	0.74	0.89	0.76	0.75	0.78
(060) Hessen	0.66	0.62	0.63	0.58	0.60	0.70	0.65	0.65	0.68	0.70	0.70	0.65	0.73	0.78	0.81	0.81	0.70	0.74	0.66	0.72	0.72	0.59	0.61	0.76	0.64	0.64	0.73
(070) Rheinland-Pfalz	0.68	0.66	0.67	0.66	0.65	0.68	0.71	0.71	0.72	0.72	0.76	0.74	0.75	0.70	0.81	0.80	0.79	0.88	0.72	0.79	0.72	0.64	0.71	0.92	0.75	0.74	0.86
(080) Baden-Württemberg	0.65	0.62	0.66	0.63	0.62	0.68	0.67	0.67	0.71	0.71	0.74	0.70	0.69	0.72	0.84	0.80	0.73	0.80	0.67	0.75	0.67	0.59	0.62	0.81	0.64	0.65	0.75
(090) Bayern	0.71	0.67	0.77	0.66	0.68	0.73	0.69	0.68	0.68	0.77	0.73	0.76	0.81	0.95	0.95	0.91	0.78	0.80	0.79	0.86	0.76	0.74	0.68	0.78	0.77	0.77	0.77
(100) Saarland	0.98	0.81	0.77	0.66	0.72	0.72	0.71	0.71	0.68	0.82	0.76	0.76	0.76	0.82	0.91	1	0.97	0.99	0.84	1	0.77	0.77	0.72	0.73	0.76	0.73	0.78
(121) Île de France	1	0.91	0.99	0.90	0.90	0.98	1	0.94	1	0.97	1	1	0.90	0.80	0.98	0.93	0.90	1	1	1	1	1	1	1	1	1	1
(131) Champagne-Ardenne	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(132) Picardie	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.96	1	1	1	1	1	1	1	1	1	1
(133) Haute-Normandie	0.92	0.92	0.96	0.85	0.84	0.91	0.92	0.89	0.95	0.92	0.95	0.92	0.88	0.96	1	0.94	0.95	1	1	0.93	0.97	0.91	0.92	0.98	0.99	0.91	0.93
(134) Centre	0.90	0.98	0.96	0.92	0.82	0.86	0.86	0.83	0.84	0.79	0.82	0.85	0.78	0.74	0.86	0.80	0.94	0.90	0.95	0.91	1	1.00	1	1	1	1	1
(135) Basse-Normandie	1	0.91	0.95	0.86	0.86	0.90	0.93	0.96	0.93	0.98	0.93	0.92	1	0.95	0.94	0.96	0.91	0.93	0.94	0.95	0.95	0.89	0.91	0.89	0.85	0.85	0.88
(136) Bourgogne	0.79	1	0.93	0.88	0.88	0.82	0.84	0.87	0.87	0.91	0.93	0.92	0.86	0.84	0.96	0.88	0.86	0.88	0.89	0.84	0.89	0.81	0.87	0.92	0.84	0.82	0.87
(141) Nord-Pas-de-Calais	1	0.93	1	1	1	1	1	0.98	0.98	0.97	0.98	0.94	0.99	1	0.99	0.94	0.95	1	1	0.93	0.92	0.82	0.88	1	0.88	0.87	0.86
(151) Lorraine	0.88	1	1	0.99	1	1	1	1	1	1	1	0.99	1	1	1	1	1	1	0.92	0.94	1.00	0.98	0.97	1	0.98	1	0.94
(152) Alsace	0.90	0.86	0.90	0.84	0.83	0.92	0.97	0.97	0.93	0.96	1	1	0.94	0.95	1	1	1	1	1	1	1	1	1	1	1	1	1
(153) Franche-Comté	1	1	1	1	1	1	1	1	1	1	0.93	0.95	0.98	0.98	1	1	1	1	0.93	1	1	1	1	1	1	1	1
(162) Pays de la Loire	0.85	1	1	0.85	0.80	0.83	0.90	1	1	0.99	0.96	0.91	0.94	0.97	1	0.98	0.97	0.97	1	1	0.98	0.91	0.94	0.97	0.91	0.91	0.90
(163) Bretagne	0.88	0.98	0.98	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(164) Poitou-Charentes	0.73	0.91	0.88	0.91	0.97	0.95	0.82	0.77	0.84	0.92	0.94	0.87	0.82	0.97	0.98	1	0.95	0.99	1	1	1	1	0.93	1	0.91	0.91	1
(182) Aquitaine	0.71	0.76	0.74	0.72	0.71	0.69	0.81	0.77	0.79	0.84	0.94	0.85	0.90	0.86	0.93	0.89	0.91	0.92	1	0.93	0.92	0.87	0.89	0.92	0.85	0.87	0.89
(183) Midi-Pyrénées	0.59	0.73	0.73	0.68	0.70	0.72	0.60	0.64	0.64	0.73	0.74	0.72	0.69	0.67	0.77	0.79	0.71	0.76	0.75	0.81	0.79	0.74	0.73	0.77	0.74	0.73	0.75
(184) Limousin	0.48	0.80	0.72	0.61	0.79	0.78	0.60	0.65	0.66	0.75	0.71	0.67	0.72	0.71	0.75	0.75	0.80	0.74	0.99	0.90	0.84	0.64	0.62	0.70	0.62	0.74	0.74
(192) Rhônes-Alpes	0.70	0.78	0.81	0.80	0.77	0.75	0.74	0.87	0.87	0.89	0.86	0.84	0.76	0.71	0.87	0.88	0.80	0.81	0.84	0.81	0.84	0.77	0.83	0.84	0.80	0.76	0.81
(193) Auvergne	0.55	0.74	0.77	0.67	0.67	0.66	0.63	0.69	0.71	0.84	0.79	0.80	0.75	0.78	0.81	0.82	0.82	0.78	1	1	0.81	1	0.86	0.89	1	0.90	0.92
(201) Languedoc-Roussillon	0.83	0.81	0.87	0.81	0.84	0.89	0.81	0.89	0.96	0.98	1	0.85	0.70	0.76	1	0.84	0.86	0.93	0.89	0.79	0.81	0.79	0.83	0.83	0.87	0.83	0.84
(203) Provence-Alpes-Côte	0.85	0.86	0.86	0.86	0.83	0.87	0.86	0.91	0.95	0.96	0.95	0.85	0.86	0.86	1	0.99	1	1	1	1	1	1	1	1	0.95	0.93	1

Cont. Table A.1 - *Output-increasing* TE by year and by FADN region

FADN region	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
(204) Corse	0.67	0.87	0.68	0.68	0.69	0.70	0.67	0.68	0.75	0.76	0.75	0.70	0.63	0.63	0.71	0.75	0.83	0.92	1	1	1	1	0.87	1	0.92	0.94	0.77
(221) Valle d'Aoste	0.49	0.55	0.64	0.60	0.50	0.63	0.54	0.57	0.62	0.64	0.65	0.71	0.58	0.59	0.67	0.73	0.62	0.55	0.47	0.70	0.57	1	0.63	0.68	0.62	0.71	0.80
(222) Piemonte	1	1	1	1	1	1	1	1	0.94	1	1	1	1	1	1	1	1	0.81	0.74	0.94	0.94	0.74	0.96	0.82	0.92	0.95	0.93
(230) Lombardia	1	1	1	0.90	0.92	1	0.97	0.97	0.96	1	1	1	1	0.96	1	1	1	1	0.89	0.99	1	0.80	1	1	1	1	1
(241) Trentino	0.86	0.88	0.87	0.97	1	1	0.78	0.82	0.85	0.87	1	1	0.73	0.63	0.81	1	1	0.98	0.79	0.96	0.96	0.87	1	1	1	1	1
(242) Alto-Adige	0.91	0.95	0.93	0.88	0.90	0.97	0.99	0.76	0.87	0.91	0.88	0.80	0.62	0.63	0.75	0.89	0.84	0.84	0.65	0.85	0.73	0.67	1	1	1	0.96	0.96
(243) Veneto	1	0.95	1	1	0.94	0.91	0.84	0.96	1	1	1	1	1	0.78	1	0.83	0.94	0.83	0.67	0.83	0.78	0.69	0.86	0.90	0.80	0.92	0.91
(244) Friuli-Venezia	1	1	1	1	1	1	0.90	1	0.84	0.82	0.89	1	1	0.60	0.72	1	0.91	0.88	0.75	0.96	0.74	0.69	0.89	1.00	0.84	0.93	0.79
(250) Liguria	1	1	1	1	1	1	0.95	1	0.86	0.96	1	1	0.83	0.92	1	1	1	0.93	0.88	1	1	1	1	1	1	1	1
(260) Emilia-Romagna	1	1	1	1	1	1	1	1	1	1	1	0.96	0.87	0.86	0.89	0.87	0.82	0.83	0.66	0.71	0.66	0.57	0.74	0.77	0.76	0.86	0.85
(270) Toscana	0.79	0.78	0.83	0.90	0.90	0.91	0.95	0.84	0.82	0.90	1	0.93	0.75	0.65	0.81	0.92	0.90	0.85	0.65	0.91	0.86	0.68	0.72	0.80	0.80	0.92	0.89
(281) Marche	0.95	0.95	0.90	0.95	0.77	0.77	0.68	0.77	0.78	0.83	0.81	1	1	1	1	0.67	1	0.67	0.69	1	0.78	0.69	0.81	0.77	0.72	0.79	0.83
(282) Umbria	0.64	0.70	0.73	0.84	0.80	0.78	0.79	0.74	0.67	0.61	0.68	0.69	0.39	0.47	0.55	0.69	0.65	0.65	0.52	0.70	0.74	0.55	0.67	0.73	0.72	0.84	0.89
(291) Lazio	0.86	0.76	1	0.85	0.94	0.98	0.84	1	0.96	1	0.92	0.92	0.75	1	1	1	1	0.74	1	0.91	0.79	0.64	0.80	0.89	0.79	0.89	0.89
(292) Abruzzo	1	1	1	0.80	1.00	0.93	0.75	0.96	0.98	1	1	1	1	0.95	1	0.84	0.92	0.79	0.62	0.96	0.71	0.82	1	0.55	0.59	1	1
(301) Molise	1	1	1	1	0.96	0.88	0.90	0.89	0.78	0.84	0.85	0.91	1	0.53	1	0.71	1	0.62	1	0.98	0.88	0.99	1	1	0.70	0.72	0.98
(302) Campania	1	1	1	1	1	1	0.76	1	1	1	0.92	1	0.86	1	0.87	0.93	0.66	0.76	0.68	1	0.81	0.70	0.81	0.89	0.88	0.90	0.88
(303) Calabria	1	1	1	1	1	0.95	0.54	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(311) Puglia	0.90	0.86	1	0.98	1	0.89	0.68	0.84	0.81	0.91	0.86	0.76	1	0.70	1	1	1	0.94	1	0.97	1	1	0.73	1	1	1	0.94
(312) Basilicata	0.78	0.74	0.74	0.71	0.70	0.73	0.63	0.77	0.72	0.79	0.85	0.74	0.66	0.87	1	1	1	0.75	0.60	0.81	0.72	0.58	0.62	0.61	0.63	0.67	0.72
(320) Sicilia	1	1	1	1	1	0.90	0.75	0.89	1	1	1	1	0.93	1	1	1	0.97	0.85	1	1	0.94	0.78	1	1	0.93	0.90	1
(330) Sardegna	0.77	0.77	0.82	0.71	0.76	0.78	0.76	0.75	0.72	0.66	0.84	0.77	0.51	0.55	0.63	0.82	0.68	0.83	0.59	0.74	0.65	0.54	0.69	0.65	0.71	0.75	0.84
(340) Belgium	0.97	0.90	0.95	1	1	1	1	1	1	0.99	1	0.99	0.94	1	1	1	1	1	1	1	0.97	0.84	0.93	1	0.97	0.95	0.98
(350) Luxembourg	0.79	0.89	0.94	0.88	0.96	0.90	0.94	0.94	0.80	0.86	0.98	0.90	0.97	0.95	0.95	1	0.87	1	0.92	0.96	1	0.93	0.85	0.87	0.77	0.86	0.83
(360) The Netherlands	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(370) Denmark	0.87	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(380) Ireland	0.51	0.59	0.65	0.47	0.49	0.52	0.51	0.59	0.55	0.61	0.59	0.60	0.53	0.52	0.61	0.64	0.58	0.64	0.92	0.72	0.71	0.68	0.63	0.60	0.64	0.70	0.66
(411) England-North	0.83	0.81	0.82	0.80	0.92	0.91	0.88	0.79	0.76	0.71	0.74	0.79	0.75	0.75	0.85	0.83	0.83	0.91	0.76	0.75	0.79	0.69	0.61	0.66	0.62	0.64	0.66
(412) England-East	1	1	1	1	1	1	1	0.99	1	1	0.99	1	1	1	1	1	1	1	0.98	1	1	0.88	0.78	0.79	0.76	0.79	0.79
(413) England-West	0.80	0.83	0.83	0.80	0.76	0.82	0.85	0.80	0.79	0.71	0.73	0.81	0.80	0.76	0.85	0.86	0.89	0.89	0.72	0.77	0.80	0.71	0.62	0.70	0.62	0.65	0.67
(421) Wales	0.66	0.69	0.74	0.64	0.62	0.68	0.67	0.65	0.60	0.58	0.63	0.68	0.64	0.63	0.66	0.78	0.78	0.77	0.70	0.72	0.68	0.60	0.65	0.60	0.57	0.62	0.56

Cont. Table A.1 - *Output-increasing* TE by year and by FADN region

FADN region	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
(431) Scotland	0.74	0.75	0.76	0.76	0.74	0.72	0.74	0.70	0.71	0.61	0.60	0.61	0.60	0.54	0.73	0.67	0.69	0.76	0.64	0.65	0.75	0.67	0.60	0.60	0.56	0.58	0.58
(441) Northern Ireland	0.68	0.63	0.66	0.61	0.57	0.64	0.61	0.58	0.60	0.61	0.58	0.58	0.54	0.65	0.75	0.71	0.63	0.67	0.80	0.80	0.79	0.82	0.66	0.64	0.57	0.57	0.53
(450) Makedonia-Thraki	1	1	1	1	1	1	0.52	1	1	1	1	0.93	1	0.59	1	1	0.79	0.83	1	0.78	0.63	0.76	0.81	0.65	0.63	0.60	0.61
(460) Ipiros-Peloponissos-Nissi Io:	1	1	1	1	1	1	0.80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.71	1	1	1
(470) Thessalia	1	0.94	0.92	1	1	1	0.98	1	1	1	0.88	0.80	0.43	0.48	0.60	0.75	1	0.72	1	1	0.66	0.70	0.67	0.51	0.51	0.62	0.71
(480) Sterea Ellas-Nissi Egaeou-Kr	1	0.95	1.00	0.96	0.97	0.94	0.81	0.97	0.94	1	0.97	0.96	0.86	0.98	1	1	1	1	1	0.82	0.75	0.77	1	0.70	0.61	0.72	0.84
(500) Galicia	0.86	0.95	0.82	1	0.91	0.96	1	0.99	0.91	0.99	1	1	1	1	1	1	0.96	0.89	1	1	0.95	1	0.97	0.87	0.77	0.90	1.00
(505) Asturias	1	0.96	0.86	1	0.64	0.70	0.73	0.92	1	0.87	1	1	1	1	1	0.97	1	1	1	1	1	1	1	1	0.80	0.91	0.71
(510) Cantabria	1	1	1	1	0.86	0.83	0.83	0.95	0.84	0.93	1	0.90	1	1	1	1	1	0.86	1	1	1	1	1	1	0.79	1	1
(515) Pais Vasco	0.83	1	1	0.92	1	0.83	0.81	0.99	0.87	0.87	0.99	0.94	1	0.76	0.88	1	0.87	0.85	0.93	1	0.80	0.87	0.96	0.97	0.85	0.95	0.92
(520) Navarra	1	0.89	0.86	0.84	1	1	0.71	0.84	0.72	0.84	1	0.95	0.90	1.00	1	0.96	0.82	0.87	0.85	0.79	0.98	0.81	0.70	0.94	0.93	1	1
(525) La Rioja	1	1	1	0.93	0.79	0.78	0.81	1	1	1	1	1	1	1	1	0.91	0.77	1	1	0.89	1	1	0.93	0.77	0.74	0.96	0.99
(530) Aragón	0.76	0.65	0.72	0.62	0.74	0.73	0.89	0.78	0.78	0.81	0.92	0.89	0.80	0.86	1	1	1	0.86	1.00	0.76	0.83	1	0.71	0.92	1	0.81	1
(535) Cataluna	0.64	0.95	0.72	0.66	0.78	1	0.92	1.00	0.83	0.92	0.76	0.84	0.75	0.64	0.83	0.90	0.73	0.75	0.60	0.63	0.75	0.61	0.73	0.71	0.68	0.78	0.83
(540) Baleares	0.91	0.67	0.67	0.62	0.67	0.68	0.99	0.98	0.78	0.79	0.80	0.83	0.62	0.59	0.94	0.99	1	1	1	1	1	0.70	0.67	0.60	0.56	0.76	0.88
(545) Castilla-León	0.86	0.97	0.88	1	0.93	0.85	0.80	0.95	0.91	1	0.84	0.81	0.68	0.77	0.97	0.98	0.87	0.95	0.94	0.80	0.85	1.00	1	1	0.95	1	0.87
(550) Madrid	0.70	0.87	0.98	0.81	1	0.79	1	1	1	1	1	1	0.81	0.71	0.98	1	1.00	1.00	1.00	1.00	1.00	1.00	1	1	1	0.90	0.83
(555) Castilla-La Mancha	1	1	1	1	1	0.90	0.87	0.90	1	0.88	0.94	0.88	0.74	0.63	0.88	0.88	0.96	0.81	0.79	0.67	0.80	0.79	0.71	0.58	0.62	0.86	0.95
(560) Comunidad Valenciana	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(565) Murcia	0.63	1	1	1	1	1	0.77	0.98	0.79	0.92	0.96	1	1	0.80	1	0.95	1	1	1	0.98	1	0.79	0.76	0.93	0.80	0.77	0.92
(570) Extremadura	0.98	0.85	1	1	0.81	0.86	0.79	0.72	0.79	0.94	0.81	0.68	0.60	0.47	0.76	0.75	0.81	0.88	0.83	0.75	0.77	0.98	1	0.80	0.66	0.83	0.80
(575) Andalucia	1	1	1	1	0.97	1	1	1	0.84	0.88	1	1	0.86	0.60	1	0.99	1.00	0.87	0.80	0.84	0.90	0.76	0.78	0.74	0.90	0.84	0.84
(580) Canarias	1	1	0.96	0.89	0.77	0.85	1	1	1	1	1	1	1	1	1	1	1	1	1	0.94	0.83	1	1	0.90	0.72	0.91	0.84
(610) Entre Douro e Minho/Beira li	0.76	1	1	1	1	1	0.46	1	1	1	1	1	1	1	1	1	1	1	1	0.97	0.92	1	0.83	0.73	0.68	0.73	0.69
(630) Ribatejo e Oeste	0.62	0.62	0.64	0.60	0.62	0.54	0.51	0.54	0.59	0.70	1	0.60	1	0.52	0.89	0.69	0.68	0.81	0.63	0.85	0.88	0.92	1	1	1	1	1
(640) Alentejo e do Algarve	0.67	0.62	0.61	0.61	0.53	0.57	0.51	0.52	0.56	0.59	0.58	0.46	0.43	0.41	0.50	0.47	0.52	0.52	0.50	0.44	0.52	0.52	0.62	0.60	0.62	0.74	0.85
(650) Açores	1	1	0.80	0.70	1	1	0.52	0.63	1	0.65	1	1	0.56	1	1	1	1	1	1	1	1	1	1	1	1	1	1
EU-12	**0.85**	**0.88**	**0.88**	**0.85**	**0.86**	**0.86**	**0.82**	**0.87**	**0.86**	**0.88**	**0.89**	**0.88**	**0.83**	**0.82**	**0.91**	**0.91**	**0.89**	**0.88**	**0.87**	**0.89**	**0.87**	**0.83**	**0.85**	**0.86**	**0.82**	**0.86**	**0.87**

Table A.2 - Malmquist Index decomposition - period 1986-2012

FADN region code and name	MI_o	ΔET	TP	$\Delta Scale$	$\Delta Shape$
(010) Schleswig-Holstein	1.75	1.07	1.68	0.98	1.00
(020) Hamburg	1.89	1.25	1.48	1.09	0.94
(030) Niedersachsen	1.75	1.11	1.64	0.96	1.01
(050) Nordrhein-Westfalen	1.50	0.91	1.71	0.97	1.00
(060) Hessen	1.51	1.10	1.40	0.99	0.99
(070) Rheinland-Pfalz	1.63	1.27	1.26	1.01	1.01
(080) Baden-Württemberg	1.52	1.15	1.29	1.02	1.00
(090) Bayern	1.58	1.16	1.36	1.01	1.00
(100) Saarland	1.01	0.78	1.23	0.97	1.08
Germany	**1.57**	**1.09**	**1.45**	**1.00**	**1.00**
(121) Île de France	2.01	1.00	2.09	1.00	0.96
(131) Champagne-Ardenne	1.66	1.00	1.73	1.00	0.96
(132) Picardie	1.99	1.00	2.11	1.00	0.95
(133) Haute-Normandie	1.98	1.05	1.90	1.06	0.94
(134) Centre	2.10	1.16	1.89	1.00	0.95
(135) Basse-Normandie	1.40	0.95	1.52	1.00	0.96
(136) Bourgogne	1.76	1.12	1.60	1.00	0.98
(141) Nord-Pas-de-Calais	1.58	0.88	1.72	1.00	1.04
(151) Lorraine	1.47	1.00	1.45	1.00	1.02
(152) Alsace	2.08	1.21	1.67	1.14	0.91
(153) Franche-Comté	0.76	1.00		1.00	
(162) Pays de la Loire	1.80	1.06	1.73	0.96	1.03
(163) Bretagne	1.66	1.00	1.67	1.00	0.99
(164) Poitou-Charentes	2.15	1.35	1.64	1.04	0.94
(182) Aquitaine	2.14	1.27	1.70	1.07	0.93
(183) Midi-Pyrénées	2.00	1.36	1.46	1.05	0.96
(184) Limousin	1.65	1.41	1.32	0.97	0.91
(192) Rhônes-Alpes	1.73	1.18	1.49	1.00	0.98
(193) Auvergne	2.04	1.70		1.00	
(201) Languedoc-Roussillon	1.51	1.01	1.55	1.01	0.95
(203) Provence-Alpes-Côte	2.08	1.18	1.61	1.14	0.96
(204) Corse	1.75	1.15	1.53	1.04	0.96
France	**1.79**	**1.14**	**1.67**	**1.02**	**0.96**
(221) Valle d'Aoste	1.44	1.63	0.86	0.99	1.04
(222) Piemonte	0.91	1.10		0.98	
(230) Lombardia	1.42	1.00	1.38	1.06	0.97
(241) Trentino	1.21	1.17	1.03	1.03	0.97
(242) Alto-Adige	1.22	1.05	1.04	1.09	1.02
(243) Veneto	1.05	1.08		1.03	
(244) Friuli-Venezia	0.81	0.79		1.00	
(250) Liguria	0.93	1.00		1.00	
(260) Emilia-Romagna	1.04	0.85	1.08	1.12	1.01
(270) Toscana	0.96	1.13	0.88	0.89	1.08
(281) Marche	0.59	0.86		0.97	
(282) Umbria	1.19	1.33		1.00	
(291) Lazio	1.00	1.04	0.97	0.96	1.04
(292) Abruzzo	1.03	1.20		0.97	
(301) Molise	0.73	1.00		0.92	

Cont. Table A.2 - Malmquist Index decomposition – period 1986-2012

FADN region code and name	MI_o	ΔET	TP	$\Delta Scale$	$\Delta Shape$
(302) Campania	0.88	0.88		1.00	
(303) Calabria	1.42	1.00		1.28	
(311) Puglia	1.09	1.11		0.90	
(312) Basilicata	0.90	0.92	0.99	0.96	1.03
(320) Sicilia	1.17	1.00		1.12	
(330) Sardegna	1.06	1.11	0.94	0.97	1.04
Italy	**1.05**	**1.06**	**1.03**	**1.01**	**1.02**
(340) Belgium	**1.38**	**0.99**	**1.46**	**0.97**	**0.99**
(350) Luxembourg	**1.36**	**0.96**	**1.42**	**0.99**	**1.01**
(360) The Netherlands	**1.73**	**1.00**	**1.73**	**0.97**	**1.03**
(370) Denmark	**3.26**	**1.03**	**3.03**	**1.37**	**0.76**
(380) Ireland	**1.57**	**1.46**	**1.14**	**0.99**	**0.95**
(411) England-North	1.15	0.79	1.47	0.95	1.05
(412) England-East	1.18	0.79	1.51	0.97	1.02
(413) England-West	1.12	0.83	1.36	0.93	1.06
(421) Wales	1.30	0.88	1.43	1.02	1.02
(431) Scotland	1.06	0.78	1.42	0.94	1.02
(441) Northern Ireland	1.36	1.01	1.36	0.99	1.01
United Kingdom	**1.20**	**0.85**	**1.43**	**0.96**	**1.03**
(450) Makedonia-Thraki	0.55	0.61	0.90	0.99	1.03
(460) Ipiros-Peloponissos-Nissi Ioniou	0.89	1.00	0.98	0.95	0.96
(470) Thessalia	0.65	0.70	1.01	0.95	0.98
(480) Sterea Ellas-Nissi Egaeou-Kriti	0.70	0.79	0.89	0.95	1.04
Greece	**0.70**	**0.77**	**0.94**	**0.96**	**1.00**
(500) Galicia	0.85	1.00		1.13	
(505) Asturias	0.69	0.85		0.95	
(510) Cantabria	0.86	1.00		1.00	
(515) Pais Vasco	1.20	1.08		1.04	
(520) Navarra	1.04	0.97		0.93	
(525) La Rioja	1.47	0.94		1.43	
(530) Aragón	1.30	1.31	1.19	0.84	0.99
(535) Cataluna	1.56	1.30	1.17	1.05	0.99
(540) Baleares	0.98	0.80		1.07	
(545) Castilla-León	1.40	0.96	1.42	1.11	0.92
(550) Madrid	1.31	1.20	1.08	1.01	1.01
(555) Castilla-La Mancha	1.05	0.95		0.97	
(560) Comunidad Valenciana	1.38	1.00		1.26	
(565) Murcia	1.78	1.45		1.06	
(570) Extremadura	1.08	0.80		1.27	
(575) Andalucia	0.96	0.83	1.16	1.06	0.95
(0580) Canarias	0.60	0.84		0.96	
Spain	**1.15**	**1.02**	**1.20**	**1.07**	**0.97**
(610) Entre Douro e Minho/Beira litoral	1.08	0.91		1.06	
(630) Ribatejo e Oeste	1.89	1.61		1.00	
(640) Alentejo e do Algarve	1.33	1.25	1.03	1.00	1.04
(650) Açores	0.97	1.00		0.84	
Portugal	**1.32**	**1.19**	**1.03**	**0.97**	**1.04**
EU-12	**1.36**	**1.05**	**1.42**	**1.02**	**0.99**

Table A.3. - Confidence intervals of Malmquist Index components at 5% level of significance

FADN region	*MIo*		*ΔET*		*TP*		*ΔScale*		*ΔShape*	
10	1.56	1.78	0.99	1.23	1.28	1.74	0.93	1.03	0.96	1.03
20	1.85	2.06	1.16	1.44	1.28	1.53	1.06	1.25	0.85	0.97
30	1.52	1.80	1.04	1.26	1.29	1.72	0.91	1.00	0.97	1.03
50	1.29	1.54	0.83	1.00	1.43	1.78	0.93	1.00	0.96	1.02
60	1.38	1.57	1.04	1.18	1.24	1.47	0.96	1.01	0.97	1.01
70	1.61	1.72	1.19	1.35	1.17	1.33	0.98	1.10	0.95	1.05
80	1.42	1.60	1.08	1.22	1.16	1.36	0.99	1.08	0.97	1.03
90	1.50	1.65	1.03	1.25	1.23	1.47	0.96	1.03	0.98	1.03
100	0.95	1.15	0.73	0.95	1.04	1.32	0.79	0.99	1.05	1.23
121	1.82	2.07	0.72	1.09	1.89	2.36	0.99	1.11	0.91	0.99
131	1.55	1.78	0.85	1.12	1.56	1.87	0.97	1.06	0.93	1.00
132	1.68	2.07	0.72	1.14	1.77	2.33	0.98	1.07	0.91	0.98
133	1.85	2.12	0.87	1.13	1.75	2.06	1.04	1.15	0.90	0.97
134	1.92	2.22	0.92	1.26	1.79	2.11	0.95	1.10	0.90	0.98
135	1.24	1.60	0.83	1.10	1.33	1.70	0.96	1.03	0.93	1.01
136	1.69	1.90	1.04	1.27	1.46	1.69	0.94	1.01	0.96	1.02
141	1.48	1.81	0.81	1.11	1.35	1.80	0.98	1.01	1.01	1.12
151	1.33	1.67	0.84	1.15	1.28	1.60	0.92	1.03	0.98	1.10
152	1.98	2.29	1.08	1.31	1.56	1.79	1.10	1.28	0.84	0.93
153	0.69	0.96	0.80	1.41			1.00	1.03		
162	1.68	1.93	0.96	1.20	1.56	1.84	0.90	1.00	1.00	1.08
163	1.57	1.92	0.87	1.18	1.50	1.85	0.99	1.04	0.96	1.01
164	2.05	2.33	1.17	1.46	1.52	1.77	1.03	1.13	0.89	0.95
182	2.03	2.29	1.12	1.35	1.59	1.81	1.07	1.16	0.88	0.94
183	1.91	2.22	1.26	1.50	1.32	1.53	1.02	1.15	0.91	1.00
184	1.57	1.79	1.19	1.56	1.12	1.45	0.91	1.12	0.84	1.00
192	1.63	1.86	1.11	1.31	1.35	1.55	0.98	1.02	0.95	1.01
193	1.92	2.24	0.98	1.92			0.96	1.30		
201	1.43	1.59	0.93	1.09	1.42	1.61	1.00	1.09	0.92	0.98
203	2.00	2.24	1.02	1.23	1.49	1.70	1.15	1.32	0.88	1.00
204	1.68	1.87	0.99	1.22	1.42	1.62	1.04	1.18	0.90	1.00
221	1.39	1.53	1.54	1.83	0.78	0.92	0.91	1.03	0.99	1.09
222	0.82	0.98	0.96	1.22			0.94	1.08		
230	1.36	1.45	0.83	1.14	1.19	1.55	0.91	1.12	0.94	1.04
241	1.13	1.26	0.54	1.24	0.91	1.24	1.01	1.32	0.81	1.06
242	1.19	1.32	1.00	1.13	0.95	1.08	1.04	1.19	0.98	1.10
243	1.00	1.14	0.96	1.22			1.03	1.11		
244	0.77	0.91	0.72	0.93			0.90	1.02		
250	0.85	0.97	0.78	1.25			0.65	1.06		
260	0.99	1.12	0.78	0.91	0.98	1.13	1.06	1.21	0.97	1.09
270	0.91	1.00	1.09	1.24	0.81	0.95	0.79	0.89	1.02	1.16
281	0.56	0.72	0.78	1.24			0.61	1.02		
282	1.14	1.29	1.23	1.49			0.96	1.01		
291	0.93	1.06	0.97	1.14	0.89	1.06	0.88	0.96	0.97	1.10
292	0.97	1.09	0.56	1.41			0.74	1.30		
301	0.69	0.81	0.64	1.38			0.54	1.21		
302	0.84	0.92	0.82	1.13			0.56	1.00		
303	1.22	1.47	0.62	1.38			0.23	1.43		
311	1.05	1.15	0.48	1.24			0.80	1.25		
312	0.85	0.95	0.87	1.01	0.92	1.07	0.87	0.95	1.00	1.10

Cont. Table A.3. - Confidence intervals of Malmquist Index components at 5% level of significance

FADN region	*MIo*		*ΔET*		*TP*		*ΔScale*		*ΔShape*	
320	1.11	1.20	0.64	1.38			0.41	1.41		
330	1.02	1.10	0.97	1.19	0.80	0.99	0.89	1.08	1.00	1.18
340	1.28	1.43	0.91	1.09	1.24	1.53	0.90	1.01	0.96	1.07
350	1.22	1.41	0.91	1.06	1.22	1.50	0.87	1.01	1.00	1.07
360	1.57	1.91	0.72	1.26	1.25	1.90	0.90	1.18	0.90	1.08
370	2.35	3.57	0.52	1.22	2.42	3.53	1.31	1.71	0.61	0.80
380	1.51	1.70	1.30	1.68	0.78	1.22	0.92	1.05	0.93	1.17
411	1.05	1.15	0.75	0.94	1.10	1.51	0.83	0.98	1.01	1.11
412	1.15	1.30	0.72	1.13	0.67	1.65	0.90	1.06	0.90	1.07
413	1.00	1.11	0.79	0.95	1.04	1.38	0.86	0.97	1.03	1.13
421	1.22	1.34	0.80	0.97	1.24	1.51	0.96	1.07	0.99	1.06
431	0.89	1.07	0.73	0.89	1.05	1.47	0.85	0.98	1.00	1.09
441	1.33	1.45	0.93	1.11	1.25	1.48	0.93	1.01	1.00	1.05
450	0.51	0.61	0.54	0.85	0.58	0.96	0.59	1.02	0.96	1.21
460	0.85	0.95	0.41	1.12	0.83	1.15	0.90	1.32	0.76	1.08
470	0.61	0.70	0.60	0.80	0.88	1.06	0.89	1.02	0.94	1.05
480	0.66	0.75	0.69	0.91	0.77	0.93	0.89	1.04	0.99	1.14
500	0.81	0.98	0.68	1.38			0.56	1.48		
505	0.65	0.80	0.69	1.23			0.26	1.11		
510	0.79	0.96	0.67	1.39			0.53	1.15		
515	1.19	1.29	1.00	1.25			0.92	1.15		
520	0.93	1.10	0.86	1.40			0.18	1.00		
525	1.46	1.53	0.80	1.35			0.34	1.63		
530	1.24	1.39	0.72	1.46	1.07	1.39	0.76	1.10	0.82	1.08
535	1.53	1.71	1.22	1.43	1.08	1.22	1.05	1.12	0.94	1.01
540	0.89	0.99	0.72	0.92			0.86	1.15		
545	1.36	1.45	0.91	1.10	1.19	1.47	0.99	1.23	0.87	1.01
550	1.23	1.36	1.12	1.33	0.95	1.14	0.90	1.06	0.98	1.06
555	0.96	1.06	0.91	1.13			0.69	0.98		
560	1.24	1.40	0.61	1.36			0.42	1.55		
565	1.75	1.94	1.34	1.70			0.95	1.17		
570	1.00	1.11	0.76	1.18			0.16	1.34		
575	0.93	1.02	0.73	0.90	1.07	1.29	0.98	1.16	0.85	0.99
580	0.58	0.71	0.81	1.24			0.91	0.98		
610	0.99	1.19	0.78	1.05			0.88	1.18		
630	1.68	1.99	0.58	1.76			1.00	1.36		
640	1.21	1.40	1.01	1.35	0.85	1.10	0.98	1.13	1.01	1.13
650	0.88	1.08	0.56	1.38			0.31	1.09		
EU-12	**1.28**	**1.48**	**0.87**	**1.23**	**1.23**	**1.56**	**0.86**	**1.13**	**0.93**	**1.05**