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Full Research Article

Human capital and rural development policy: evidence from European FADN regions

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Abstract. This paper analyses the evolution and policy drivers of the productivity of farmers' human capital in EU agriculture from 1986 to 2010. The empirical analysis employs farm data sourced from the Farm Accountancy Data Network Standard Results as well as Eurostat's information on farm holders' educational-attainment levels. Productivities of human capital are measured by the shadow prices for three levels of educational attainment of farm family labour, computed using Data Envelopment Analysis with variable returns to scale, and related to a Malmquist index of total factor productivity and to selected policy variables. The results indicate that productivities of farmers' human capital trend upwards and are positively associated with rural development payments.

Keywords. productivity of human capital, shadow prices, technical efficiency, productivity growth, specific education, agricultural change.

JEL Codes. 047, 015, D24, E24, C43.

1. Introduction

Human capital requires investment in learning new skills, both through traditional schooling and postschool job training. It also represents a crucial source of productivity gains and long-term economic growth. According to the neoclassical approach (Mankiw *et al.* 1992), human capital is a fundamental input into the aggregate production function, and its accumulation explains the process of economic growth. On the other hand, the Schumpeterian approach holds that growth results from the initial endowment of human capital, which influences a country's or region's capability to innovate and catch up with the technology of the leader area (Nelson and Phelps 1966; Benhabib and Spiegel 1994).

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At any rate, few economists would dispute that for most of the world's agriculture, immaterial inputs – including human capital – are now crucial for total factor productivity (TFP) growth. This growth is no longer a resource-based process driven by material input accumulation, but a productivity-based process driven mainly by immaterial input accumulation (Fuglie 2015; Ball *et al.* 2016). Knowledge-intensive work environments are increasingly common, creating a situation in which human capital relates to entrepreneurial outcomes more than ever before (Unger *et al.* 2011). It has also long been known that education in agriculture enables farmers to allocate inputs more efficiently (Welch 1970) and to optimise their information searches (Ram 1980). The educational system imparts the ability to summarise information from various sources and to engage in nonroutine problem solving (Swaim 1995; Gasson 1998). Technical education favours participation in agri-environmental schemes (Dupraz *et al.* 2002), improves eco-efficiency (Van Passel *et al.* 2009; Picazo-Tadeo *et al.* 2011) and increases the value added per annual working unit (Carillo *et al.* 2013).

In this context, how is European agriculture responding to these challenges? In principle, education offers higher returns for individuals working in any sector experiencing technological progress (Blundell *et al.* 1999). Hence, the returns on farmers' education are linked to a changing agricultural technology and production structure. If these conditions do not change, farmers' incentive to acquire education dwindles (Huffman 2001). Now, there is little doubt about the existence of an ongoing demand for new skills in European agriculture (European Commission 2014). Crucial to the present analysis, public policy also plays a role in incentivising the accumulation of human capital.

Since 2005, as a result of the Fischler Reform and subsequently the CAP Reform 2014–2020, direct support (Pillar I subsidies) and structural policies (Pillar II payments) have pursued a more entrepreneurial approach to agricultural business management through increased market orientation and competitiveness (Clark, 2009). Corporate efficiency and environmental safeguarding became key issues. In terms of direct-support policies, farm aid has largely been decoupled and subject to cross-compliance. As for structural interventions, rural development policy has been strengthened with funds and policy instruments aimed at facilitating the provision of environmental goods. In addition, activities have been diversified in a more targeted and locally tailored manner.

It is expected that the stronger market orientation of direct support will foster aggregate productivity gains for the sector as a whole. This prediction rests partly on the assumption that only high-performing farms will survive due to their ability to thrive in an environment that promotes continuous learning and problem solving (Henke *et al.* 2011) and partly on the belief that the transition from a traditional agricultural policy to a rural one may improve the policy communities and networks relevant to farmers (Keating and Stevenson 2006) or the farmers' business strategies (Clark 2009; Severini and Tantara 2013). Productivity-enhancing effects may result also from the rural development plans and human-capital transfers carried out within the CAP. However – and this is the central focus of this paper – these reforms could also have increased the productivity of higher-order cognitive skills, an issue that has wide-ranging policy relevance because higher returns for human capital may attract this input into the sector (Olper *et al.* 2014; Garrone *et al.* 2019).

Although these arguments suggest the existence of a link between the CAP reforms and human-capital productivity in agriculture, this relationship has yet to be investigated empirically.[1] There is a simple way of testing the hypothesis that the greater CAP market orientation has enhanced the productivity of human capital in agriculture: determining whether the relative shadow price of the human capital embodied in European farmers has increased after the CAP reforms. Therefore, this paper primarily aims to measure the relative shadow price of farm family labour for three levels of educational attainment from 1986 to 2010. These relative shadow prices are computed by applying the data envelopment analysis with variable returns to scale (DEA-VRS) for all EU-27 Farm Accountancy Data Network (FADN) regions, for all years for which information on farm holders' trainings is available. DEA has been widely used in growth accounting studies because it does not impose restrictive functional forms on the production frontier and is much more directly interpretable than other approaches in terms of production theory (Arcelus and Arocena 2000; Filippetti and Peyrache 2013). Due to data availability, we focus on three levels of educational attainment: low, medium and high (further details are given in the research materials that are available online).

Because TFP growth influences the productivity of human capital (and vice versa), a second and complementary task of this paper is to measure the growth in TFP by computing a Malmquist TFP index (which is possible only for a balanced panel of EU-12 FADN regions). To the best of the authors' knowledge, no other study has measured a TFP index for European agriculture at the regional level over so long a period. It should be emphasised that some of the utilised data are not readily available from public sources, as explained in greater detail in section 4 and the research materials.

The analytical framework proposed in this paper may be replicated to evaluate the productivity of human capital for similar situations in other sectors, particularly when labour is mainly self-employed and lacks a market price. The analysis could also be extended to provide absolute (as opposed to relative) shadow prices for human-capital services, which could be used in a DEA-based cost–benefit analysis (see, e.g., Kortelainen and Kuosmanen 2006).

The remainder of the paper adheres to the following structure. Section 2 reports on the history of the CAP and provides some descriptive statistics. Sections 3 and 4 focus on the methodology and data used, respectively. Section 5 describes and comments on the empirical results, and the paper offers concluding remarks in section 6. The paper also includes a research materials section that describes the empirical framework further and reports some robustness checks.

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

Table 1 reports the percentage of farmers with full agricultural training, our proxy for high human capital, as calculated from Farm Structure Survey (FSS) data, as well as the percentage of the population aged 15 to 64 years with tertiary education, as calculated from Eurostat data.

Educational attainment is a poor indicator of the extent to which individuals possess the cognitive skills and technical knowledge required to carry out more demanding and better-paid jobs; nonetheless, the table highlights the well-known gap between rural and urban educational levels (Swaim 1995). Whereas the percentage of the population with tertiary qualifications,

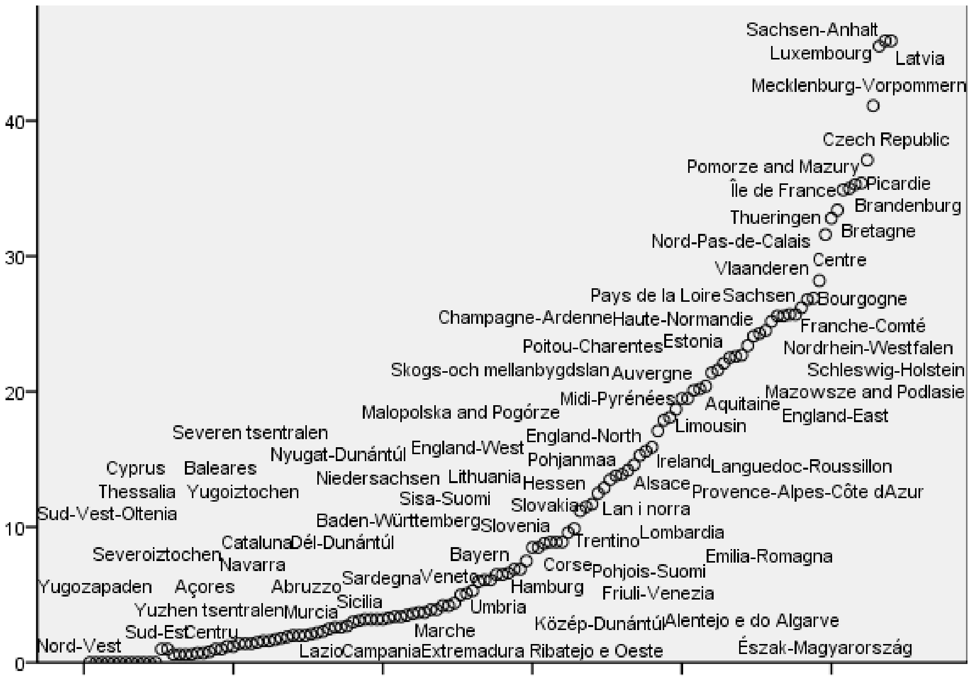
[1] There is, however, an empirical literature on the relationships between CAP reforms and TFP. We comment on this literature, whose results are rather diverse, when discussing our evidence in section 5.

Table 1. Human capital in EU agriculture and economy, 2010 and latest available years.

Areas	% farmers with full agricultural training, 2010	% population from 15 to 64 years with tertiary education, 2010	% farmers with full agricultural training, 2016	% population from 15 to 64 years with tertiary education, 2018
EU-6	14.9	21.8	16.1	26.2
EU-9	14.4	23.9	16.4	29.1
EU-10	13.6	23.8	14.3	29.0
EU-12	12.0	24.1	12.1	29.4
EU-15	12.3	24.1	12.5	29.7 9
EU-25	12.6	23.2	13.8	29.1
EU-27	11.3	22.7	11.5	28.5

NB: EU-6, EU-9, EU-10, EU-12, EU-15, EU-25, EU-27 to be defined in the research materials.
Source: Own elaborations on FSS and Eurostat Regional statistics.

Figure 1. Farm holders with full agricultural training (%), 2010.



Source: Own elaborations on FSS and Eurostat Regional statistics.

measured in either 2010 or 2018, is not appreciably sensitive to the EU aggregate considered (if anything, it increases at each EU enlargement), the percentage of farmers with full agricultural training (either in 2010, available from our dataset, or in 2016, the latest year for which we can retrieve some aggregate information) tends to decrease with each EU enlargement.

The cross-sectional distribution of the percentage of farm holders with full agricultural training across FADN regions is further depicted in Fig. 1.

The percentage ranges from 0.2% in Ipiros-Peloponissos-Nissi Ioniou to 45.9% in Latvia and Luxembourg. Generally, the most rural regions exhibit the lowest percentage of farmers with full agricultural training. The significant differences observed in human capital across EU regions may be explained by divergent agricultural education systems, agricultural structures and farm-size distributions. Yet, human capital has improved over time. According to FSS data, in 1990, the percentage of farm holders with medium and high human capital in EU-12 was 12% and 7%, respectively. In 2010, these figures were 20% and 12%. It could be asked whether policies, by affecting the incentives for human-capital accumulation, have favoured or hampered this improvement. Before dealing with this question in the following sections, we proceed to give a detailed account of the most relevant changes of the CAP in this sphere.

The CAP has undergone several changes since the 1980s, including production limits to reduce surpluses (milk quotas were first applied in 1984); during this time, much emphasis has been placed on environmentally sound farming. The first fundamental reform occurred in 1992 with the MacSharry Reform, followed by "Agenda 2000" in 1999, the Fischler Reform in 2003 and the CAP Reform 2014–2020 in 2013.

In 1992, the MacSharry Reform caused a shift from market to producer support. Cereal, oilseeds and livestock intervention prices were scaled down. Computed on the basis of average regional yield levels, per-hectare compensatory payments were also introduced, along with compulsory set-aside requirements attached to these payments.

In 1999, the "Agenda 2000" Reform further cut intervention prices, bringing them closer to world market levels while aligning cereal, oilseed and livestock payments in order to promote the competitiveness of European agriculture. "Agenda 2000" also initiated the Rural Development Policy, a wider structural strategy of decentralised spatial management for rural territories in Member States (MSs). This policy sought to encourage sustainable development by valorising both agricultural and nonagricultural activities.

In 2003, the Fischler Reform was introduced, promoting sustainability and cohesion. Farmers received a single payment calculated by dividing the total payments received over a historical period by the number of hectares on the farm. Previously related to the number of animals or the milk quota size, premiums were largely added to the flat-rate compensation per hectare. Single farm payments favour the use of land relative to other inputs in agricultural production and reduce the yields of many commodities; their total output response is less than the price support (Sckokai and Anton 2005). Furthermore, these payments severed the link between production and farm income support. This decoupling sought to orient farmers towards the market while still providing them with a degree of income stability. Farmers were free to produce what they judged most profitable, so long as the land was used for agriculture. Income stability was intended to serve as compensation for higher production standards with regard to consumer protection, animal welfare and environmental conservation (compared to many non-European countries). Anyone failing to fulfil this 'cross-compliance' condition risked a reduction in their direct income payments (Moro and Sckokai 2013). The reform was in place from 2005 onwards, but decoupled payments fully replaced direct aid only in 2007.

The Fischler Reform has also strengthened the role of services in fostering agricultural human capital and competitiveness. Each MS must set up an advisory system aimed at farms in order to satisfy compliance requirements. The Programme for Rural Development (2007–2013) provided funding for the supply of advisory services and other actions[2] aimed at human-capital transfer (Contó *et al.* 2012). Yet, the background of both advisory services operators and private business consultants was often agronomic and not business management, resulting in outdated or incomplete professional skills (Clark 2009). Indeed, the fact that the returns for professional and technical training are lower than those for managerial training (Blundell *et al.* 1999) prompts the need to promote entrepreneurship through education.

In 2013, CAP contents were again redesigned over the programming period 2014–2020. In particular, single farm payment has been unpacked into different payments targeting different goals and partly tailored to farm-specific characteristics. According to European Regulations, only some of these payments (base payment, greening payment and payment for young farmers) are mandatory for MSs, unlike other kinds of payment (coupled, for less favoured areas, for small farms).

The introduction of the greening payment, conditional on compliance with certain "agricultural practices beneficial for the climate and the environment", reflects the EU legislators' intention to provide a more consistent justification for CAP instruments, emphasising their role in pursuing environmental sustainability (European Commission 2010 a, b; Matthews 2013; Cimino *et al.* 2015; Erjavec and Erjavec 2015). The key role of services has also been strengthened during the period 2014–2020. In particular, the Programme for Rural Development pays greater attention to knowledge transfer and information actions, including vocational training and skills acquisition by farmers (or SMEs operating in rural areas),[3] and to advisory services, farm management and farm support.[4]

3. The empirical methodology

The shadow price associated with an input indicates how much more output could be obtained by increasing the amount of that input by one unit. It is a measure of the opportunity cost of that input and reflects its marginal productivity. In the field of productivity measurement, shadow prices are estimated when market prices are inapplicable, unknown or inappropriate. They can also be used as appropriate indicators of input productivities. Carrying out intercountry comparisons of agricultural productivity, Coelli and Prasada Rao (2005) and Nin-Pratt and Yu (2010) estimated shadow input prices in order to obtain input cost shares as market prices are distorted due to government intervention. Ten Raa and Mohnen (2002) used shadow input prices as a valuation of input productivities unaffected by market power, disequilibrium in factor holding, suboptimal capacity utilisation and returns to scale.

[2] Examples include vocational training for consultants (Measure 111) and support for cooperation in the development of new products, processes and technologies (Measure 124).

[3] Examples include training courses, workshops and coaching, as well as short-term agricultural exchanges and visits to farms (Article 14 of Council Regulation (EU) No 1305/2013)

[4] These include three types of measures: supporting farmers and related operators in the use of advisory services to improve economic and environmental performance and resilience to climate change, encouraging the establishment of farm management and promoting the training of advisers.

Shadow prices may be estimated through nonparametric linear programming or through parametric regression analysis. Examples of the nonparametric approach include the study of industrial wastes (Reig-Martínez *et al.* 2000), volunteer work (Destefanis and Maietta 2009), hospital outputs (O'Donnell and Nguyen 2013), biodiversity (Sipilainen and Huhtala 2013), undesirable outputs (Leleu 2013), and water and wind resources (Ilak *et al.* 2015). DEA-based shadow prices have also been used in cost–benefit analyses of environmental services (Kortelainen and Kuosmanen 2006).

Within a nonparametric framework, shadow prices are determined as the solution to multiplier or dual linear programming problems. They are the multipliers revealed by individual producers in an effort to maximise their relative efficiency (Fried *et al.* 2008). In this paper, in order to determine the shadow prices of inputs, we rely on the DEA-VRS technique,[5] implemented through the solution of the multiplier (dual) problem $\text{BCC}_D{}^I$ proposed by Banker *et al.* (1984):

$$
\begin{aligned}
&\text{BCC}_D^I\,(x_i, y_i):\\
&\max_{\mu_i,\, \nu_i,\, \omega_i} \quad \mu_i y_i + w_i\\
&v_i x_i = 1\\
&\mu_i y_i - v_i x_i + w_i \le 0\\
&\mu_i \ge 0,\ v_i \ge 0
\end{aligned}
\qquad (1)
$$

where $\mathbf{x}$ is the input vector and $\mathbf{y}$ is the output vector, $\mathbf{n}_i$ and $\mathbf{m}_i$ are the shadow prices or multipliers of inputs and outputs, respectively, and w_i is an indicator of returns to scale. Note that whereas $\mathbf{n}_i$ and $\mathbf{m}_i$ must be greater than or equal to zero, w_i may be positive, negative or zero, which makes it possible to use the optimal value of this variable to identify the nature of returns to scale. This input-oriented problem is solved by finding values for $\mathbf{n}_i$ and $\mathbf{m}_i$ that maximise output "values" $\mathbf{m}_i\mathbf{y}_i + w_i$, subject to a normalising constraint on input "values" (which avoids the occurrence of infinite solutions to the problem) and to the constraint that efficient output "values" must be smaller than or equal to input "values". As a consequence of these constraints, shadow prices computed from different frontiers are not directly comparable (Kuosmanen and Kortelainen 2006). However, it is possible to compare the ratio between the shadow prices of two inputs, which is the marginal rate of technical substitution between these inputs (Ouellette and Vigeant 2016). For this reason, our analysis always considers the shadow prices of family-labour categories as ratios calculated vis-à-vis the shadow price of paid labour.

The computation of shadow prices may provide values equal to zero for some outputs or inputs. Input shadow prices are zero in cases of slack in the primal envelopment form. It is also possible to have a zero value in the case of multiple optimal solutions (Olesen and Petersen 2015). Indeed, the estimated DEA frontier is not smooth. Its kinks in primal space correspond to flats in dual space that fail to yield unique shadow prices for strongly efficient units, that is, observations with zero slacks in the primal envelopment form (Chambers and Färe 2008). In order to solve this problem, Olesen and Petersen (2015) proposed a "facet

[5] When the data are expressed on "an average per farm" basis (as in this paper), it is sensible to stick to a variable-returns-to-scale technology (Coelli and Prasada Rao 2005).

analysis" of the convex hull, making it possible to identify well-defined shadow prices for strongly efficient units as well.

DEA-VRS can also be used in order to compute Malmquist indexes for TFP growth. This index, explained in detail in the research materials, is one of the most widely used tools for measuring TFP growth of firms, industries and countries (Mizobuchi 2017). It enables decomposition of TFP growth into movements towards or away from the production frontier, technical progress and scale-related factors.

We chose a nonparametric approach for the computation of both shadow prices and the Malmquist index, because, unlike econometric estimation, this approach does not rely on any assumption about the functional form of input–output relationships or of stochastic disturbances.

4. The data and the empirical specifications

The bulk of data for this study were obtained from FADN and refer to a representative farm at the regional level, commonly used in sector models based on linear programming (Jonasson and Apland 1997) and for intercountry productivity analysis (Rizov *et al.* 2013). We are aware that reliance on these data may lead to the neglect of some interesting heterogeneities characterising the phenomenon under scrutiny. However, microdata across FADN regions are unavailable across a time span sufficiently long to allow investigation of the CAP reforms. Furthermore, the literature contains few aggregate analyses concerning the role of entrepreneurial human capital in local development (Marvel *et al.* 2016). More generally, it has been stressed recently that the use of microdata in policy evaluation may lead to biased results, because analyses based on them neglect the presence of spillover effects (see, e.g., instance Deaton 2019).

Data on representative farms at the regional level can be downloaded from the Standard Results section of the FADN database. For the purpose of this study, version A1 of FADN Standard Results was downloaded,[6] because it refers to a representative farm at the regional level for the period 1989–2012. Meanwhile, *Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria* (CREA; formerly *Istituto nazionale di economia agraria*, or INEA) provided version A1, with 34 variables for the period 1986–1988 (RICA RI/CC/882 rev. 3, described in Dell'Acqua 1995).

We also relied on the Eurostat FSS (for the period 1986–2010), which is the only harmonised source for human-capital data in EU agriculture; it periodically measures the percentage of farm holders with practical, basic and full agricultural training. Unfortunately, no such information is available for paid labour. Note that the territorial location of the FSS corresponds to NUTS2 regions, which are not necessarily the same as FADN regions (see the research materials for an explanation of the matching procedure across these territorial definitions and for other information about the data).

Table 2 reports the descriptive statistics of the variables. On average, the commercial farm employed 1.28 family work units, the farmer plus another (part-time) family member, and 0.64 paid work units in the time period under consideration. Family labour is much more likely to have low- or medium-level educational attainment (which corresponds to the information available from European Commission 2014).

[6] http://ec.europa.eu/agriculture/ricaprod/database/consult_std_reports_en.cfm

Table 2. Descriptive statistics of the main variables.

Variable	Units	Mean	St. Dev.	Minimum	Maximum
Products	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	“	293,228	263,265	8,211	2,095,475
Paid labour	AWUs*	0.64	1.37	0	15.99
Family labour	FWUs*	1.28	0.32	0.38	2.68
Family labour - Low HK	“	0.55	0.40	0	2.03
Family labour - Medium HK	“	0.62	0.20	0	1.22
Family labour - High HK	“	0.19	0.36	0	2.01
Compensatory payments/Gross farm income	%	4.83	8.12	0	37.24
Decoupled subsidies/Gross farm income	“	5.62	10.74	0	51.09
Human capital transfer payments/Gross farm income	“	0.2	0.85	0	12.26
Rural development payments/Gross farm income	“	3.15	6.48	0	45.73

* AWU, Annual Working Unit, and FWU, Family Working Unit, are defined as 2,200 hours worked annually.
Source: Own elaborations on FADN and FSS data, Eurostat Regional statistics.

Table 3. DEA model specifications.

	Malmquist index	Shadow prices
Output	Agricultural products (total output)	Agricultural products (total output)
Inputs	Materials, Capital, Paid labour, Family labour	Materials, Capital, Paid labour, Family labour - low human capital, Family labour - medium human capital, Family labour - high human capital
DEA orientation	Output-increasing	Input-saving
FADN regions	EU-12	EU-12, EU-15, EU-25, EU-27
Years	1986-2012	1986, 1990, 1993, 1997, 2000, 2005, 2010

The specification of the production set used for computing the Malmquist index differs from that used for shadow prices (see Table 3). For the Malmquist index, the analysis is output oriented and labour is measured in work units (FWUs for family labour and AWUs for paid labour), as is common practice in the measurement of agricultural productivity. Disaggregation of family labour in human-capital categories was not used, because this information was not available for all years. Furthermore, because calculation of the index requires the use of balanced panel data, only the EU-12 regions were considered. On the other hand, when computing shadow prices, all available regions among those belonging to EU-27 were included in the sample, and family labour was divided into three categories according to human-capital endowment. In this case, an *input orientation* was deemed more appropriate for evaluating the productivity of varying levels of human capital because of the latest CAP objectives, which do not encourage input intensification.

5. Results and discussion

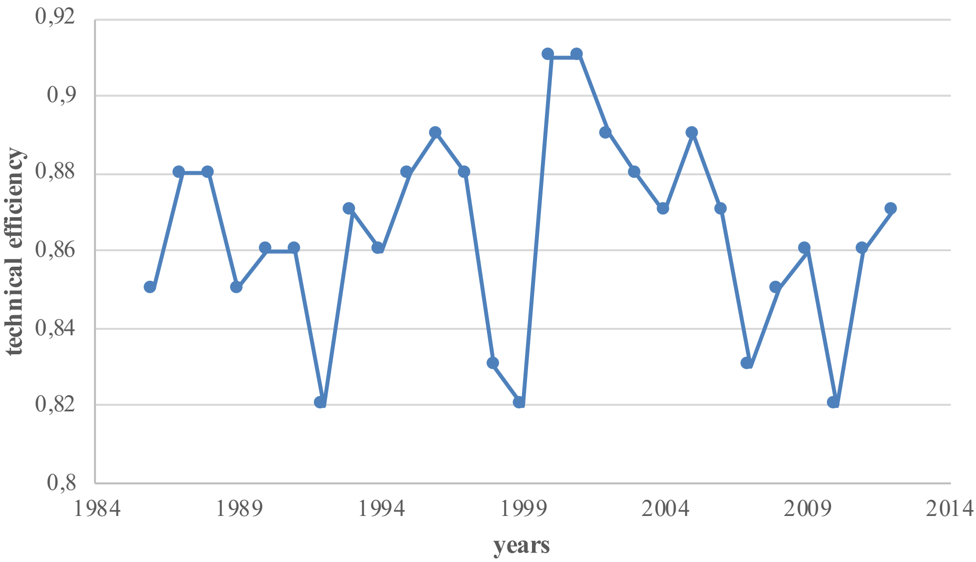
5.1 Productivity growth and the Malmquist index

The first step of our empirical analysis, a propaedeutic for the calculation of the Malmquist index, is the estimation of annual production frontiers. We use an *output-oriented* DEA-VRS on the balanced panel data of 88 EU-12 regions for period 1986–2012. Indeed, in cross-country multilateral productivity comparisons, the analysis is usually output oriented (Arnade 1994).

From Fig. 2, it is evident that the mean level of *output-increasing* technical efficiency decreases in the reform years (1992, 1999 and 2006–2007) before rebounding upwards.

The details for each region (available in the research materials) indicate that the FADN regions that always lie on the frontier are Champagne-Ardenne, Comunidad Valenciana (in line with the results in Maudos *et al.* 2000) and the Netherlands, followed by Denmark,[7] Picardie and Bretagne. Efficiency has lagged in Eastern England over the past few years, in line with the demonstrated decrease in UK TFP compared to that of neighbouring countries (Burgess and Morris 2009). Increasing returns to scale slightly prevail (53% of observations).

Figure 2. The average level of *output-increasing* technical efficiency in EU-12, 1986-2012.



Source: Own elaborations on FADN data.

[7] Both the Netherlands and Denmark are FADN regions in their own right.

Table 4. Geometric mean of annual productivity growth components in EU-12.

Year/Period	MI	DET	TP	DScale	DShape
1987	1.03	1.04	0.98	1.01	1.00
1988	1.00	0.99	1.01	1.00	1.00
1989	1.01	0.97	1.06	0.99	1.01
1990	1.00	1.00	1.00	1.00	1.00
1991	1.02	1.02	0.99	1.00	0.99
1992	1.04	0.92	1.09	0.95	1.07
1993	0.99	1.08	0.94	1.07	0.93
1994	0.99	1.00	1.01	1.00	0.99
1995	0.98	1.03	0.96	1.01	0.99
1996	1.02	1.01	1.01	1.00	1.01
1997	1.03	0.98	1.03	1.00	1.00
1998	1.00	0.94	1.09	0.93	1.03
1999	1.03	0.99	1.03	1.02	1.03
2000	1.02	1.11	0.92	1.04	0.98
2001	0.99	1.00	0.98	1.02	0.99
2002	1.06	0.99	1.13	0.96	1.00
2003	0.96	1.01	0.93	1.01	1.00
2004	1.04	0.95	1.10	0.94	1.06
2005	1.02	1.04	0.97	1.07	0.96
2006	1.01	0.98	1.03	0.97	1.01
2007	1.02	0.95	1.07	0.98	1.03
2008	1.00	1.02	0.97	1.06	0.96
2009	1.02	1.01	1.01	1.01	0.98
2010	0.99	0.97	1.06	0.98	1.00
2011	0.99	1.04	0.95	1.04	0.98
2012	0.97	1.01	0.96	1.01	1.00
1987-2012	1.008	1.002	1.009	1.001	0.999

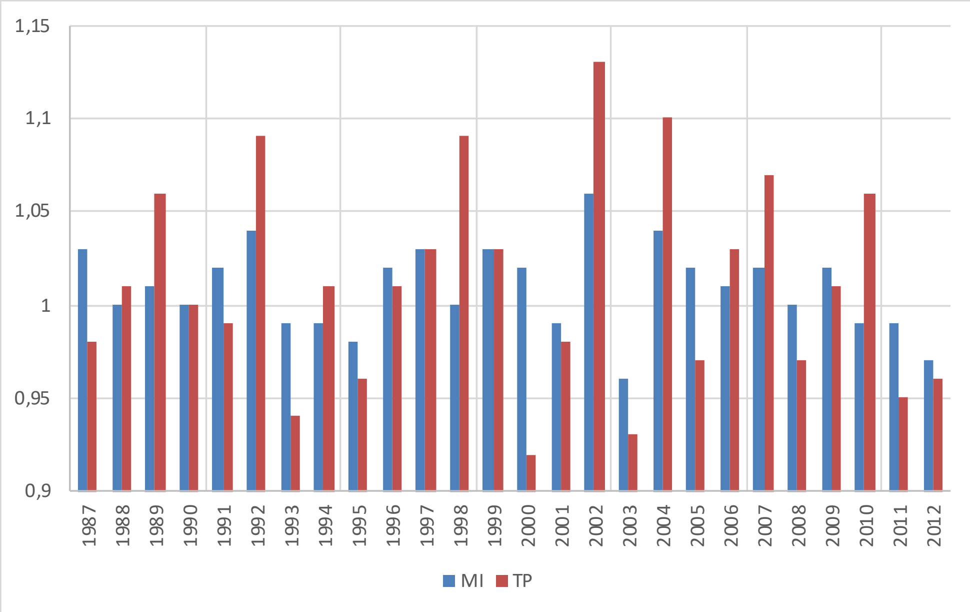
Source: Own elaborations on FADN data.

Table 4 reports the geometric mean for each component of the *output-increasing* Malmquist index, which was computed using the *FEAR* library of R. On average, the annual TFP growth index in EU-12 throughout 1987–2012 is equal to 1.008, mainly due to technical progress, with an annual mean index of 1.009. There is little efficiency change, and the contributions to productivity growth of scale and shape variations are even less pronounced.

More details for TFP growth in each region are available in the research materials. As in previous research (Bernini Carri 1995), Denmark shows the highest rate of TFP growth. At the national level, France, Germany and the Netherlands follow patterns already observed for similar periods in other studies (Coelli and Prasada Rao 2005).

Fig. 3 shows the aggregate evolution of TFP growth and technical progress. These variables do not exhibit very marked differences over time. However, the years following the MacSharry Reform (1993–1998) and the recession years (2010–2012) are associated with a productivity slowdown.

Figure 3. The Malmquist index (MI) and technical progress (TP) in EU-12, 1987-2012.



Source: Own elaborations on FADN data.

Finally, we find a strongly significant negative Kendall's rank correlation coefficient (with a value of -0.21) between technical progress and the number of family-labour work units with low human capital, which suggests that a low level of human capital has constrained productivity growth. This result stresses the importance of immaterial input accumulation for TFP growth within EU agriculture as well.

5.2 The shadow prices of family labour

Table 5 reports the relative shadow prices of the three family-labour categories, differentiated according to their human-capital endowment, for various sample cuts and treatments of the strongly efficient units (traditional vs. facet analysis). The shadow price of paid labour, which is unlikely to differ substantially from market wage, is taken as numéraire. Hence, this relative price is the marginal rate of technical substitution between paid labour and family labour with low, medium and high levels of human capital, respectively. The *Benchmarking* library of R was used to compute the shadow prices for the traditional analysis, while the Qhull code (developed by Brad Barber, Davi Dobkin and Hannu Huhdanpaa) was used for the "facet analysis", which makes it possible to identify well-defined shadow prices for strongly efficient units as well.

We present results for both the full sample and a sample restricted to regions from the EU-12 countries, because we do not want to draw conclusions that may be crucially affected by the EU enlargements after 1986. Indeed, our previous analysis of TFP growth relates only

Table 5. Marginal rates of substitution between paid labour and family labour by human capital categories.

Years	Full sample							EU-12 sample						
		Traditional analysis			Facet analysis				Traditional analysis			Facet analysis		
		Human capital endowment			Human capital endowment				Human capital endowment			Human capital endowment		
	N	low	medium	high	low	medium	high	N	low	medium	high	low	medium	high
1986	76	0.46	1.09	1.62	0.50	0.54	0.68	76	0.46	1.09	1.62	0.50	0.54	0.68
1990	86	0.20	0.38	1.79	0.41	0.73	0.62	86	0.20	0.38	1.79	0.41	0.73	0.62
1993	68	0.17	0.53	4.74	0.36	0.60	0.76	68	0.17	0.53	4.74	0.36	0.60	0.76
1995	71	0.17	0.86	0.71	0.53	0.57	0.66	70	0.17	0.87	0.72	0.53	0.57	0.66
1997	71	0.08	0.29	2.32	0.46	0.48	1.08	71	0.08	0.29	2.32	0.46	0.48	1.08
2000	97	0.27	0.98	1.30	0.48	0.85	0.71	92	0.26	1.01	1.29	0.50	0.85	0.70
2005	122	0.76	1.40	4.15	0.44	1.11	1.08	95	0.70	1.42	4.04	0.39	0.97	1.00
2010	135	1.41	2.24	4.06	0.43	0.89	0.84	94	1.16	1.58	3.68	0.38	0.64	0.52

Source: Own elaborations on FADN and FSS data.

to EU-12 countries. Taking first the results for the traditional analysis, we find that for both samples, the marginal rate of substitution for family labour with a low level of human capital increases up to one and a half from 1986 to 2010 (yet only in 2005 and 2010 does this marginal rate of substitution show an appreciable increase); the marginal rate of substitution for family labour with a medium level of human capital almost doubles; and the marginal rate of substitution for family labour with a high level of human capital triples. Switching to the results that include the facet analysis for strongly efficient units, we find that the marginal rate of substitution for family labour with a low level of human capital is basically constant, whereas the marginal rates for the other categories of family labour show a gently rising trend (on average, high human capital is slightly more priced that medium human capital). Summing up, for both the traditional and the facet analysis, we observe increases in the relative shadow price of medium and high human capital over the period under scrutiny.

It is unlikely that the conclusions are affected by the changing number of observations in the year samples, because they hold true for the EU-12 samples for 1990, 2000, 2005 and 2010, which have very similar numerosity (86 to 94 observations). Moreover, the results are not very likely to be driven by exit of inefficient farms from the market. To be sure, we do not have farm-level data, but Table 6 reports the mean (input-oriented) efficiency and the number of efficient FADN regions characterising the production set used for the calculation of shadow prices.

Both mean efficiency and the number of efficient observations rise up to 2000, but in 2005 and 2010 they fall back to levels very close to those of 1986 (once more, this is true for the full and the EU-12 sample). This at least suggests that the gradual disappearance of inefficient farms is not a key factor of the evolution of marginal rates.

We carry out two further robustness checks on the above results, which we detail in the research materials. First, we computed shadow prices by including production subsidies

Table 6. Mean input-oriented efficiency and percentage of efficient observations.

Years	Full Sample			EU-12 Sample		
	N	Mean Input-oriented Efficiency	% of efficient observations	N	Mean Input-oriented Efficiency	% of efficient observations
1986	76	0.94	0.58	76	0.94	0.58
1990	86	0.93	0.48	86	0.93	0.48
1993	68	0.95	0.57	68	0.95	0.57
1995	71	0.97	0.69	70	0.97	0.69
1997	71	0.96	0.65	71	0.96	0.65
2000	97	0.97	0.69	92	0.96	0.70
2005	122	0.96	0.56	95	0.95	0.56
2010	135	0.95	0.53	94	0.96	0.56

Source: Own elaborations on FADN and FSS data.

among the outputs. We get more erratic figures for marginal rates than in Table 5, but the general picture does not change. Secondly, we used quality-adjusted data for paid labour as numéraire. Again, we get results similar to those in Table 5, although they show a lower increase for the medium- and high-human-capital categories.

An explanation for the rising trends in the relative shadow prices of family labour (particularly with medium and high human capital) could in principle be found in technical progress. However, technical progress subsides in the last years of the sample, when the increase in shadow prices is even more marked. Hence, other factors, including policy effects, must be considered.

In order to explore the relevance of these policy effects, we follow Han *et al.* (2014) and perform a robust analysis of correlation among our variables of interest. Table 7 reports three different indicators: (a) Kendall's simple rank correlation coefficients between the marginal rates of substitution for family labour categorised by human-capital endowment (and obtained through the traditional analysis on the full sample) and the percentages of different kinds of CAP-related variables on gross farm income; (b) Kendall's partial rank correlation coefficients between the same variables as above (they measure the rank correlation between the two above sets of variables, controlling for the influence on both of them of a third variable, the cumulative Malmquist index,[8] CMI); (c) Kendall's coefficients of concordance among marginal rates, CAP variables and CMI. Coefficients of concordance robustly test the concordance in rankings among two or more variables. In Table 7, all variables are robustly netted out of region and year fixed effects. We do so by applying a median polish procedure.[9]

The evidence from Table 7 can be summed up as follows. Compensatory payments, which were the backbone of the pre-Fischler Reform policy, are almost never significantly

[8] We cumulate the Malmquist index, obtaining a proxy of the level of technological capability, because all other variables are measured in levels. The cumulation of the index is carried out following the procedure suggested in Tone and Tsutsui (2017).

[9] The median polish is a data analysis technique that enables the robust measurement of various effects in a multi-factor model (Hoaglin *et al.* 1983).

Table 7. Kendall's coefficients.

	Human capital categories	Kendall's simple rank correlation coefficient) between CAP variables and marginal rates of substitution for family labour by human capital categories.	Kendall's partial rank correlation coefficient) between CAP variables and marginal rates of substitution for family labour by human capital categories. CMI as confounder.	Kendall's coefficients of concordance among CAP variables, marginal rates of substitution for family labour by human capital categories and CMI.
Compensatory payments/ Gross farm income	High HK	0.05*	0.05*	0.31
	Medium HK	-0.01	-0.01	0.30
	Low HK	-0.02	-0.01	0.31
Decoupled subsidies/ Gross farm income	High HK	-0.01	0.00	0.30
	Medium HK	0.10***	0.10**	0.33
	Low HK	0.02	0.02	0.33
Human capital transfer payments/ Gross farm income	High HK	-0.01	-0.01	0.27
	Medium HK	0.04	0.13**	0.30
	Low HK	-0.02	-0.02	0.29
Rural development payments/ Gross farm income	High HK	0.00	0.01	0.35*
	Medium HK	-0.02	0.04*	0.37**
	Low HK	0.05*	0.05*	0.39***

NB: CMI is the cumulative Malmquist index. All variables are netted out of region and year effects (computed through median polish). Stars denote coefficient significances:
* means a p-value < 0.1; ** a p-value < 0.05; *** a p-value < 0.01.
Source: Own elaborations on FADN and FSS data.

associated with the marginal rates (and CMI). Human-capital transfer payments and decoupled payments are positively associated only with the marginal rates for medium levels of human capital. For human-capital transfer payments, these findings align with previous evidence indicating that the relationship between entrepreneurship outcomes and entrepreneurship education and training programmes is lower for training-focused educational interventions than for academic-focused educational interventions (Martin *et al.* 2013). On the other hand, decoupled payments are different from zero only in the last two years. A longer time span of application might have yielded a more significant correlation for this policy. In any case, according to our evidence, only rural development payments are associated with the marginal rates across all categories of human capital.

On the whole, our evidence points to a favourable assessment of CAP reforms. They are associated with a higher productivity of family labour, and the apparently ineffective compensatory payments were replaced by more relevant policies. The results, however, suggest that the association between higher productivity and rural development payments is more robust than that for decoupled payments, and support previous evidence on the ineffectiveness of training-focused educational interventions. This finding implies that the CAP reforms of the past decades, which have gradually increased the budget for rural development and promoted the economic self-sufficiency of communities through investment in local partnership, have favourably influenced the productivity of farmers' human capital.

It is interesting to compare these results with those from the empirical literature on the CAP reforms and various measures of productivity, mainly TFP (Mary 2013; Rizov *et al.* 2013; Kazukauskas *et al.* 2014; Boulanger and Philippidis 2015; Smit *et al.* 2015; Latruffe and Desjeux 2016; Dudu and Kristkova 2017). It is difficult to summarise the very diverse results obtained in these papers. The gist of their evidence, however, is that the impact of CAP instruments on productivity depends very much on the type of instruments. Decoupling seems to have on the whole a positive impact on productivity. Moreover, an important channel for productivity improvement is the increased specialisation in more productive farming activities. In particular, several studies (Latruffe and Desjeux 2016; Boulanger and Philippidis 2015; Smit *et al.* 2015; Dudu and Kristkova 2017) have argued that there may be heterogeneous effects across different types of rural development payments (such as less-favoured-areas payments, agri-environmental measures and investments in human capital and physical capital). Therefore, future research on the productivity of human capital should consider in greater detail the impact of different types of rural development subsidies and analyse its evolution for various types of agricultural production.

6. Concluding remarks

This paper provides evidence about the evolution of the productivity of family labour endowed with different levels of human capital across the EU FADN regions and about the association of this evolution with TFP and changes in the CAP. The issue is relevant for agricultural growth because TFP growth in today's agriculture is driven largely by human capital and other immaterial inputs. We find in section 5 that low human-capital accumulation may constrain TFP growth across EU regions. It has also been noted in section 2 that there are still significant differences in farmers' human-capital endowment across EU regions. We then ask whether the CAP, by affecting the incentives for human-capital accumulation in agriculture, has favoured the attraction of this input into the agricultural sectors of EU regions.

We measure the productivity of farm family labour for different levels of educational attainment (low, medium and high) using the relative shadow prices obtained by applying DEA-VRS to data sourced from the Standard Results of the FADN. Subsequently, these shadow prices are associated with indicators of CAP measures and a Malmquist TFP index.

Our evidence points to an increasing trend for the shadow prices of all categories of family labour, but in particular for those with medium and high educational attainment. In relation to policy, we find a robust association between productivity growth, shadow prices of human capital and rural development payments. Decoupled subsidies and training transfers are also associated with higher productivity in the case of low and medium levels of human capital, but this evidence is less pervasive. The policy implication we draw from these results is that rural development payments are more relevant than other kinds of payments in enhancing TFP growth and human-capital productivity.

The findings of our study have wide-ranging policy relevance, because higher returns for human capital may reduce the outflow of labour from agriculture. Adverse economic conditions caused by the global economic crisis have reinforced the arguments for job creation in agriculture. For example, the European Commission's recent "Communication on the Future of the Common Agricultural Policy (CAP)" identified fostering jobs in rural areas and attracting new people into the agricultural sector as key policy priorities (European Commission 2017). Looking ahead to the post-2020 CAP, the ongoing shift to rural development seems to be the right direction to pursue. Yet, as explained at the end of the previous section, further investigation in this field is required. A related issue concerns the greater attention paid to knowledge transfer and information actions in the CAP Reform 2014–2020. In fact, it remains to be seen whether these policies can overcome the strictures of previous training-focused educational interventions (Martin *et al.* 2013). Future research on these fields will of course take advantage of greater variation in the data across time.

Finally, in this study, shadow prices have been used to evaluate the services of an input lacking a market price, that is, human capital. In future research, this analysis could be extended to provide absolute (as opposite to relative) shadow prices for human-capital services, which could be used in a DEA-based cost–benefit analysis.

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