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In Memory of Ornella W. Maietta

Ornella W. Maietta passed away on 18th April 2019, after a long battle against cancer fought with the dignity that marked her whole life.

Ornella got her bachelor degree in Agriculture in 1987 at the University of Naples Federico II and the Specialization degree in Agricultural Economics in 1991 at the Centro di Specializzazione in Economico Agrarie per il Mezzogiorno, Portici (NA). Then she enrolled the M.Phil. in Land Economy at the University of Cambridge, UK where she graduated in 1993. Finally, she got her PhD degree in Agricultural Economics and policy at the University of Siena in 1997.

Soon after she got a position as researcher at the then Department of Agricultural Economics and Policy of the University of Naples Federico II. Then she moved to the Department of Economics and Statics of the same University where she was serving as Associate Professor of Economic Political.

Ornella's contributions to the profession focuses mostly on two broad areas of research, namely:

a) the economics of innovation where she provided key contributions on the methodology for estimating the farm/firm efficiency and productivity – she was the recipient of the 2002 best young economist paper by the European Review of Agricultural Economics/European Association of Agricultural Economists and soon after she published an important book on the analysis of efficiency that has been the reference textbook for the last generation of production economists – as well as on the role of human capital in generating innovation and growth with a focus on university-firms R&D collaboration as a driver of innovation especially for low-tech industry;

b) the economic analysis of non-profit sector, with a wide set of contributions ranging from the analysis of cooperatives to socially responsible consumption, from fair trade consumption to school meals and care sector, to some contributions that tried to bridge between the two broad areas of research analyzing the role of social capital and innovation.

Ornella was very active also in the profession being a member of the Italian Association of Agricultural and Applied Economists – AIEAA since its establishment in 2011 and having served as Associate Editor of Bio-based and Applied Economics – BAE from 2012 to 2018.

Ornella was an excellent economist, an effective mentor of generations of young economists, and a true friend of many of us. We will always remember her brilliant economic mind as well as the high quality of her academic commitment and her pursuit of excellent in study and research. But we will mostly miss the human touch she put in whatever she did, the mutually respectful relationships she was able to develop and the supportive and loyal collaboration she provided to whoever worked with her, primarily the young economists.

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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,

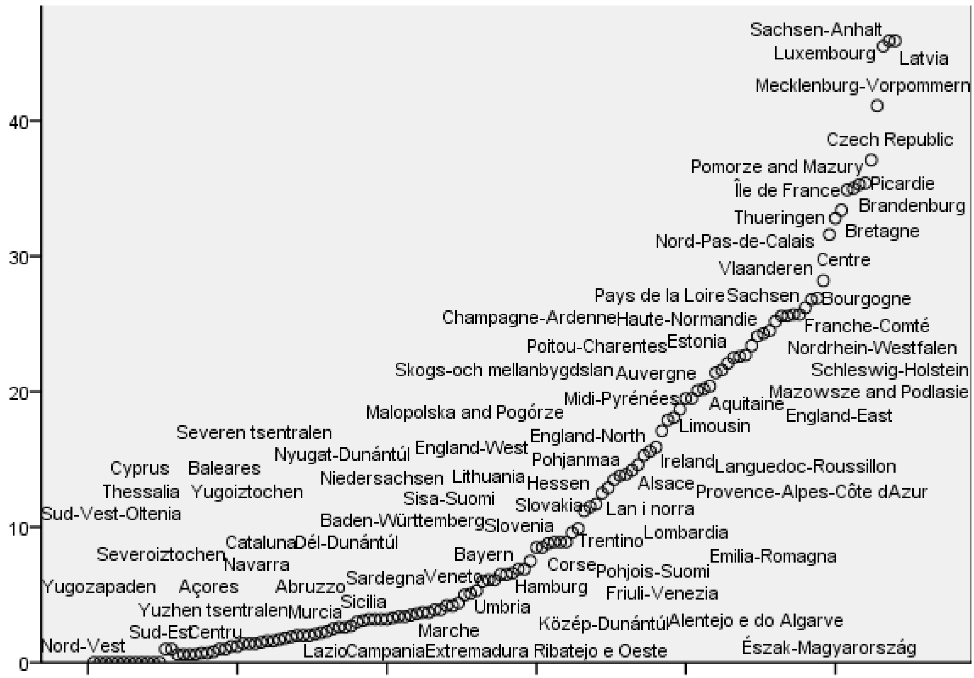
[1] There is, however, an empirical literature on the relationships between CAP reforms and TFP. We comment on this literature, whose results are rather diverse, when discussing our evidence in section 5.

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 BCC_D^I proposed by Banker *et al.* (1984):

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

where **x** is the input vector and **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

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[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).

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[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

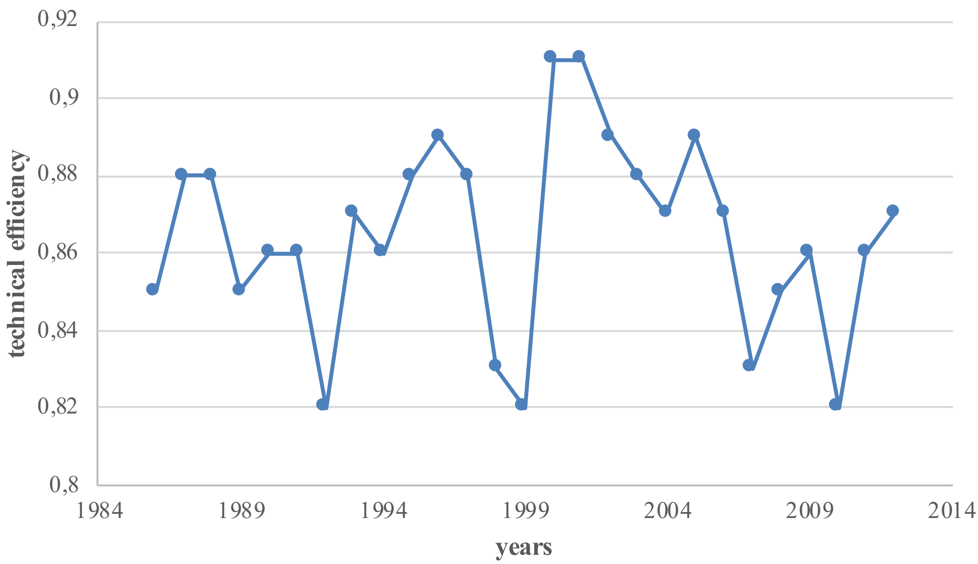
5.1 Productivity growth and the Malmquist index

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

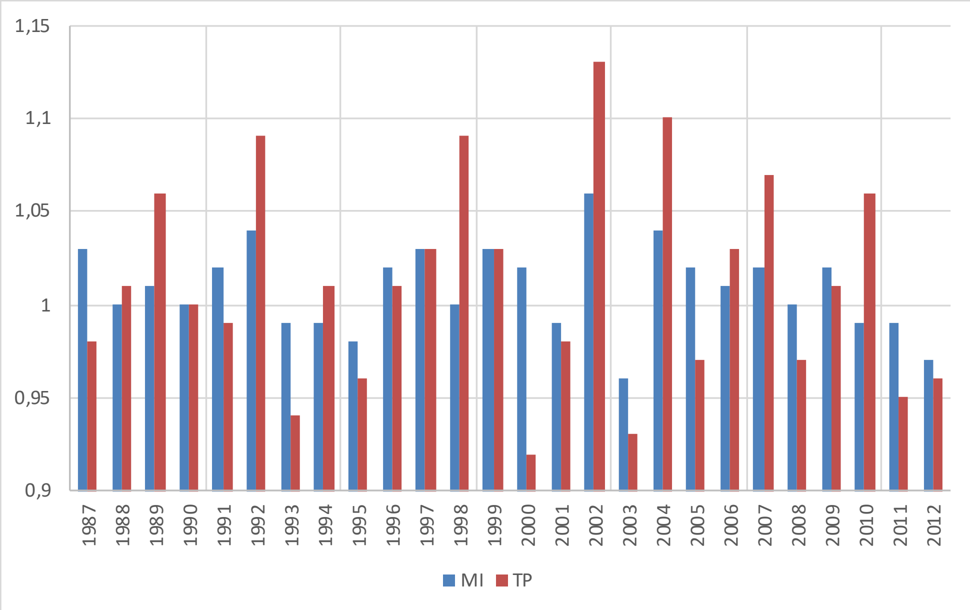
Source: Own elaborations on FADN data.

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 multifactor 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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Full Research Article

Export propensity and intensity in the wine industry: a fractional econometric approach

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Abstract. Using export market shares as a measure of international competitiveness, this paper studies wine exports in terms of propensity and intensity. Based on data for the period 1999-2014, a two-part fractional regression model is applied. The results suggest that for importing countries GDP per capita, their own wine production, and EU membership have a positive effect on the probability of importing wine but tend to evolve inversely to market shares, as taste for variety becomes more important. Additionally, export propensity is positively affected by regional trade agreements, common language, similarity of religious culture, wine production in the exporting country, and the exporting country being from the Old World, while export intensity is boosted by common language and wine production in the exporting country. Bilateral distance has a negative effect on both margins of trade.

Keywords. globalisation, international trade, market share, fractional regression model.

JEL codes. F14, L66.

1. Introduction

International competitiveness has become a topic of growing interest over the last decades. The concept of competitiveness is multifaceted and multidimensional (De Grauwe, 2010), and researchers with such different backgrounds as economics, politics, management and history have all studied this concept. In economic literature, the roots lie in the international economic theories of Adam Smith, David Ricardo and their followers. A definition of competitiveness, as given by the European Commission is the ability "to sustainably produce and sell goods and services on a given market, in such a way that buyers prefer these goods to those offered by competitors" (European Commission, p. 12, 2014). On the other hand, the Organisation for Economic Co-operation and Development suggests it is the "ability of companies, industries, regions, nations, and supranational regions to generate, while being and remaining exposed to international competition, relatively high factor income and factor employment levels on a sustainable basis" (Hatzichronologou, p.20, 1996).

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These definitions suggest that competitiveness can be observed from different points, namely at a company, sector, or national level. While ratios of financial profitability are a predominant indicator of performance for companies and the sectors of which they are composed, a high-performing country is one with positive trade balance (Cardebat, 2019). This means that, although there is no "national decision" regarding trade in the sense of a centralized decision, the "national decision" is the sum of the decisions made by its companies.

The well-known export market share is a simple but informative measure of competitiveness that allows direct trading positions to be established and was used, for example, by Banterle and Carraresi (2007), Wijnands *et al.* (2008), and Carraresi and Banterle (2015). Generally, this indicator is calculated by dividing the exports of a country by the total exports of a trading area and it is a measure of the degree of importance of a country, henceforth called country *i*, within the total exports of that trading area. The market share is given by a fractional variable bound by 0 and 1, being 0 if country *i* does not export and being 1 when all exports of the area are made by country *i*.

In econometric modelling the fractional nature of this dependent variable provides limitations, in particular with linear specifications, where predicted values can be outside the boundaries [0, 1], resulting in meaningless outcomes. Therefore, the fractional regression model (FRM) developed by Papke and Wooldridge (1996, 2008) seems to be a preferable approach. Moreover, by considering a two-part model (2P-FRM) the aim is to estimate two different effects of explanatory variables: on the one hand, the effect on the decision of two countries establishing an international trade relationship (export propensity) and, on the other hand, the effect on the decision about how much to trade (export intensity). Following a similar logic, Bouët *et al.* (2017) estimated Cognac export propensity and intensity using the Heckman's procedure to correct a sample selection issue. Comparatively, the 2P-FRM has the advantage of not requiring an exclusion restriction (Ramalho *et al.*, 2011).

The global intensification of international trade have been accompanied by a wave of research estimating macroeconomic determinants mainly through the gravity framework to explain trade flows in value or volume (Bergstrand 1989; McCallum 1995; Anderson and van Wincoop 2003; Silva and Tenreyro 2006; Anderson and Yotov 2012; Cirera *et al.* 2016). Inspired by Newton's law of gravity, the gravity model sets out to explain trade between an exporting country and an importing country based on their economic masses and the distance between them. It follows that economic masses (generally represented through the GDP) are expected to positively influence trade, while bilateral distance is expected to have a negative effect. Over time, researchers have added more variables to the model and some works highlight the importance of studying the impact of trade agreements, transport costs, purchasing power, and cultural proximity, among other determinants, on international trade patterns.[1]

Wine is a good example of a product increasingly globalised during the last five decades, presenting diversified geography of production and consumption and fierce competition between countries and even among local wine regions. Studies on the global alcohol markets, and more specifically wine, have been multiplying in the last decades. Anderson *et al.* (2018) presented historic facts about alcohol consumption and highlighted the study from Holmes and Anderson (2017) to state the more recent trend of convergence in national consumption

[1] However, generally, such analyses do not take into consideration the contribution from the exporting countries to total imports in the destination country using, for example, market shares.

patterns of alcohol as a result of globalisation. Despite social, political, and fiscal differences among countries, consumption levels have decreased in "traditional" consuming countries (e.g. France, Italy, and Portugal) and increased in other countries without a tradition of wine consumption (e.g. China, Russia, and USA) (Smith and Mitry, 2007; Dal Bianco et al, 2013). Additionally, other topics were also studied such as the potential market implications of Brexit (Anderson and Wittwer, 2017), the emergence of Asia in the beverage market (Anderson, 2019), and the impact of climate change on wine industry (Anderson, 2017; Ashenfelter and Storchmann, 2016a, 2016b). A complementary strand of the literature deals with microeconomic factors of competitiveness. For example, Bargain *et al.* (2018) use a qualitative approach to discuss key comparative advantages of 16 wine-producing countries, and Ugaglia *et al.* (2019) dedicate several chapters to the study of the industrial organization of Old and New World wine producing countries.

Based on the gravity model, but considering the fractional nature of the explained variable, which leads to the application of the FRM, this research aims to contribute to the debate and provide further insight into the dynamics of international trade. To the best of our knowledge, there are no published studies that use the FRM to analyse the competitiveness of an industry. Specifically, a 2P-FRM is applied to data on wine exports from the main fifteen producing countries to 193 partner countries, between 1999 and 2014, taking into account explanatory variables inspired by the gravity equation.

After this introduction, the paper is organized as follows: Section 2 presents the model framework and the data used; Section 3 presents the results and discussion; and Section 4 concludes.

2. Material and methods

Given that the variable of interest y, i.e. market share, is a proportion defined and observed only in the interval $0 \leq y \leq 1$, an approach capable of dealing with a bounded and fractional response variable is required. Standard linear specifications can become inconsistent since they do not guarantee predicted values within the boundaries [0,1]. Following the seminal papers of Papke and Wooldridge (1996, 2008), the FRM is recommended since it presents advantages in relation to linear methods or other common solutions of the literature such as logit, probit, Tobit and Heckman sample selection model. Unlike the FRM, all these methods do not guarantee predictions within the meaningful interval [0,1] (Ramalho *et al.*, 2011). Comparing in particular with the Heckman model, the FRM presents also the advantage of not requiring an exclusion restriction, which is useful in empirical practice and, following Schwiebert (2018), avoids severe biases due to the imposition of an incorrect restriction. The FRM is a non-linear model that does not require transformations for values at the boundaries, accounting for the non-linearity in the data, while being fully robust under generalized linear model assumptions (Gallani *et al.* 2015). Observations at the extremes of the distribution are included based on the assumption that $E(Y|X) = G(X\beta)$, where fitted values are guaranteed within the unit interval by $0 \leq G(\cdot) \leq 1$. Papke and Wooldridge (1996) suggest the quasi-maximum likelihood (QML) method for estimations of β, which is based on the maximization of the Bernoulli log-likelihood function $LL(\beta) \equiv y \log[G(X\beta)] + (1 - y) \log[1 - G(X\beta)]$.

Furthermore, if there is a high concentration of observations at the boundary 0, Ramalho *et al.* (2011) advise that it is better to consider a two-part model. The 2P-FRM is constituted of a binary model for the discrete component (0 or 1) and a fractional model for the continuous component. Choosing between one- or two-part models depends on the interpretation of the zeros based on the existence or not of two decision mechanisms for zeros and positive values [Ramalho *et al.* (2011) also suggest a P test to compare the two models]. In international trade, by the estimation of a two-part model, it is presumed that a country as representing all of its firms has two distinct decisions to make: the first is whether to establish a trade relationship with another country (export propensity) and the second concerns the amount to be traded (export intensity). If none of the companies from a country *i* decides to export to a country *j* (e.g., because costs are too high for potential profit), then the decision of country *i* is to not export to country *j*.

Therefore, in the 2P-FRM of this work, the first part estimates the factors influencing the probability of the wine of country *i* being imported by a certain country *j* and it can be defined as

$$\text{share}_{ijt}^{*} = \begin{cases} 0 \text{ for } share_{ijt} = 0 \\ 1 \text{ for } share_{ijt\varepsilon}(0,1) \end{cases} \tag{1}$$

$$Pr(share_{ijt}^{*} = 1|X_{ijt}) = E(share_{ijt}^{*}|X_{ijt}) = F(X_{ijt}\,\beta_1) \tag{2}$$

where $share_{ijt}$ is the market share of country *i*'s exports as a proportion of the total of country *j*'s imports in year *t*, $F(\cdot)$ is a non-linear conditional mean specification and β_1 is a vector of coefficients for the covariates in X_{ijt}.

The second part of the model considers only the observations of (1) where country *i*'s wine was imported, i.e. positive outcomes, to estimate the factors influencing the magnitude of a market share of country *i* in country *j*. It can be represented as

$$E[share_{ijt}|X_{ijt}, share_{ijt} \in (0,1)] = M(X_{ijt}\,\beta_2) \tag{3}$$

where in $M(X_{ijt}\,\beta_2)$ the regressors X_{ijt} are the same as the first part (despite not being required) and $M(\cdot)$ is also a non-linear conditional mean specification but not necessarily the same specification as $F(\cdot)$.

Hence, following Ramalho *et al.* (2011), $E[share_{ijt}|X_{ijt}]$ can be defined by

$$E[share_{ijt}|X_{ijt}] = M(X_{ijt}\,\beta_2) \cdot F(X_{ijt}\,\beta_1) \tag{4}$$

But to correctly interpret the estimated coefficients of non-linear econometric models it is advisable to estimate average and total partial effects. As x_{ijt} is a covariate of vector X_{ijt}, an average partial effect (APE) will be computed for the first part of the model to estimate the effect of x_{ijt} on the probability of a good (in this case wine) of country *i* being imported by a certain country *j*:

$$\frac{\partial\, Pr(share_{ijt}^{*} = 1|X_{ijt})}{\partial x_{ijt}} = \beta_1 f(x_{ijt}\,\beta_1) \tag{5}$$

Similarly, another APE will be computed for the second part to estimate the effect of x_{ijt} on the magnitude of a non-zero market share of country *i* in country *j*:

$$\frac{\partial E[share_{ijt}|X_{ijt}, share_{ijt} \in (0,1)]}{\partial x_{ijt}} = \beta_2 m(x_{ijt}\,\beta_2) \tag{6}$$

Finally, a total partial effect (TPE) will be computed to estimate the effect of x_{ijt} on the magnitude of any (including zero) market share of country *i* in country *j*:

$$\frac{\partial E[share_{ijt}|X_{ijt}]}{\partial x_{ijt}} = \frac{\partial M(X_{ijt}\,\beta_2)}{\partial x_{ijt}} F(X_{ijt}\,\beta_1) + \frac{\partial F(X_{ijt}\,\beta_1)}{\partial x_{ijt}} = M(X_{ijt}\,\beta_2) \tag{6}$$

Inspired by the literature on the gravity model (Bergstrand 1989; McCallum 1995; Anderson and van Wincoop 2003; Silva and Tenreyro 2006; Anderson and Yotov 2012; Cirera *et al.* 2016), the covariates that could influence the wine market share are: geographic distance between countries *i* and *j* ($dist_{ij}$); GDP per capita of importer *j* in year *t* ($gdppc_{jt}$); wine produced in countries *i* and *j* in year *t*-1 (respectively, $prod_{it-1}$ and $prod_{jt-1}$); exporter *i* being an Old World country (old_i); the annual average exchange rate between the currencies of countries *i* and *j* in year *t* (er_{ijt}); importer *j*'s European Union (EU) membership status in year *t* (eu_{jt}); the existence in year *t* of regional trade agreements (RTA) between countries *i* and *j* (rta_{ijt}); the same official language in countries *i* and *j* ($lang_{ij}$); and countries *i* and *j* sharing common religion beliefs ($relig_{ij}$).[2]

As regards the expected sign of the explanatory variables, distance should have a negative effect on the probability of wine trade and on market shares as this is a proxy for transport costs. On the other hand, the existence of a regional trade agreement between two countries should reduce trade costs and, consequently, may have a positive effect. The same is expected for the effect of wine production in the importing country because more wine produced means possessing a greater stock to export. Exporting countries from the Old World may also present some advantage in wine trade due to their experience. Sharing a common language or common religion beliefs should also have a positive effect in both parts of the model because it represents higher cultural proximity.

Moreover, the sign of the effect provoked by an explanatory variable may not be the same in the first and second parts. For example, the GDP per capita of importing countries represents purchasing power, which should increase the probability of trade and quantity traded but can have a different impact on market shares. In fact, a hypothesis to be tested in the results section is that higher purchasing power may lead importing countries to search for differentiation, therefore spreading their imports across more countries.

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[2] The effect of tariff and non-tariff measures on wine trade have also been studied using the gravity model. The literature shows that specific tariffs may be a deterrent to trade (Dal Bianco *et al.*, 2016; Dal Bianco *et al.*, 2017) or not have a significant effect on certain wines (Gouveia *et al.*, 2018; Macedo *et al.*, 2019, 2020). However, there is an ongoing debate about non-tariff measures as the papers published on this subject relatively recent and scarce (Dal Bianco *et al.*, 2016; Santeramo *et al.*, 2019). Dal Bianco *et al.* (2016) find that only some non-tariff measures present a significant negative effect on wine exports, while Santeramo *et al.* (2019) find more of a positive impact of some non-tariff measures in wine imports. Although recognizing the relevance of this issue, it was felt that it deserves a deeper analysis, which is beyond the scope of this paper, i.e. the application of the FRM to international wine trade.

Similarly, wine production and EU membership of importing countries may have a positive impact on the probability of trade because it may represent a higher degree of cultural openness to wine consumption, however that may also result in a taste for variety that would have a negative impact on market shares.

Regarding the exchange rate, depreciation of an exporter *i* is expected to have a positive impact on market shares, because exports of country *i* become cheaper for importers *j*, while the converse will be true if exporter *i*'s currency undergoes appreciation. However, as suggested by Chaney (2016), the effect on the probability of country *i* exporting to *j* may be the opposite because, in the presence of fixed costs and liquidity constraints, a depreciation will also mean that the value of domestic assets abroad decreases and, therefore, foreign markets become less accessible to some firms of country *i* whilst appreciation will have the opposite effect. These two effects of exchange rate are not incompatible considering a two-part model. The first part of the model should be more sensitive to fixed costs constraints because it refers to the factors affecting the probability of trade. On the other hand, the second part of the model should not be sensitive to fixed costs constraints because it only considers existent trade relationships. Studying French wine exports, Cardebat and Figuet (2019) also identified that variations in exchange rates can lead to quality sorting, in the sense that higher-quality wines are less sensitive to exchange rate movements.

The model is applied to the fifteen main wine producers[3] (Argentina, Australia, Chile, China, France, Germany, Greece, Hungary, Italy, Portugal, Romania, Russia, Spain, South Africa and USA), focusing on 193 trade partners, all of which represent around 89% of world bottled wine exports during the period 1999-2014. Regarding the explained variable, data for wine exports of the main exporting countries and total imports of each destination country are from the COMTRADE database[4] in US dollars. The computation of the market share in this work measures the weight that an exporting country *i* has on total exports to a certain country *j* (or, in other words, on the total imports of a certain country *j*). About the explanatory variables, the sources are: World Development Indicators (WDI) database for GDP per capita in current US dollars and nominal exchange rate in local currency unit per US dollar (used to compute the exchange rate of exporting countries per 1 currency unit of importing countries); International Organisation of Vine and Wine (OIV) for wine production data; Cardebat (2019) for Old World countries[5]; EU official website[6] for EU membership dummy variable; and Gravity database from *Centre d'Études Prospectives et d'Informations Internationales* (CEPII) for bilateral distance in kilometres weighted by population, religious proximity[7], dummy for common official language and dummy for regional trade agreements. Descriptive statistics of all variables considered in the paper are present in Table A.1 in Appendix.

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[3] In this paper the sample considers the main wine producers instead of the main exporters to limit bias. Data on worldwide wine trade is not completely trackable and, consequently, they do not distinguish export from re-export. For that reason, countries such as United Kingdom, Switzerland and Hong Kong appear among the main wine exporters in COMTRADE database without producing relevant quantities of wine.

[4] Harmonised system codes starting by 220421

[5] Contrary to Cardebat (2019), in this study Hungary is included in the group of Old World countries for having a historically relevant wine industry (Luptak *et al.*, 2016).

[6] Website: https://europa.eu/.

[7] Index from Disdier and Mayer (2007) calculated by adding the products of the relative proportions of Catholics, Protestants and Muslims in the exporting and importing countries. Higher values in this index mean sharing more common religion beliefs.

3. Results and discussion

In order to assess the robustness of the results, the 2P-FRM is estimated assuming four alternative non-linear conditional mean specifications (cauchit, logit, probit, and loglog) for $F(\cdot)$ and $M(\cdot)$. Based on RESET and Goodness-of-functional-form (GOFF) tests (Ramalho *et al.* 2011), the results suggest adopting the logit specification in both parts of the model (see Table A.2 in Appendix).[8] Therefore, the results of the estimations with logit are presented in Table 1.[9] Columns (1) and (3) refer to the coefficients estimated for the export propensity (equations 1 and 2) and the export intensity (equation 3), respectively. Table 1 also presents the estimations of two APEs for each explanatory variable: in column (2) the effect on the

Table 1. 2P-FRM estimations, Average Partial Effects and Total Partial Effect.

	(1)	(2)	(3)	(4)	(5)
Variables	Export propensity		Export intensity		TPE
	β_1	APE	β_2	APE	
GDP pc importer (log)	0.349***	0.057***	-0.167***	-0.014***	-0.003**
	(0.029)	(0.004)	(0.032)	(0.003)	(0.001)
EU importer	1.037***	0.170***	-0.292***	-0.024***	0.000
	(0.145)	(0.024)	(0.105)	(0.009)	(0.005)
Production importer (t-1) (log)	0.127***	0.021***	-0.054***	-0.004***	-0.001
	(0.012)	(0.002)	(0.012)	(0.001)	(0.001)
Production exporter (t-1) (log)	0.824***	0.135***	0.661***	0.054***	0.038***
	(0.047)	(0.007)	(0.066)	(0.005)	(0.003)
Old World exporter	0.772***	0.127***	-0.066	-0.005	0.007
	(0.082)	(0.013)	(0.117)	(0.010)	(0.005)
Exch. rate (log)	-0.069***	-0.011***	0.038**	0.003**	0.001
	(0.013)	(0.002)	(0.016)	(0.001)	(0.001)
RTA	0.611***	0.100***	0.071	0.006	0.010**
	(0.107)	(0.017)	(0.102)	(0.008)	(0.004)
Distance (log)	-0.278***	-0.046***	-0.620***	-0.051***	-0.029***
	(0.060)	(0.010)	(0.054)	(0.005)	(0.003)

[8] RESET and GOFF tests to the specification also reject the one-part model, which corroborate with the results of the P test suggested by Ramalho et al (2011). Additionally, estimations of the 2P-FRM with a sample of 154 exporting countries (the maximum number for which information is available) were attempted but the specification was rejected by RESET and GOFF tests. However, the results are fairly similar. The only differences in signs and significance of coefficients estimated are that, in the 1st part, religious proximity is not statistically significant and, in the 2nd part, exchange rate is not significant while RTA is positive and significant. These results are available upon request.

[9] For robustness of analysis, estimates were also made by splitting the sample into two sub-periods: before and after the financial crisis of 2008. The results do not indicate any marked differences between the two sub-periods (Table A.3 in Appendix).

Variables	(1)	(2)	(3)	(4)	(5)
	Export propensity		Export intensity		TPE
	β_1	APE	β_2	APE	
Common language	1.486***	0.244***	1.469***	0.121***	0.080***
	(0.138)	(0.022)	(0.106)	(0.009)	(0.005)
Religious proximity	1.644***	0.270***	-0.141	-0.012	0.014**
	(0.192)	(0.031)	(0.149)	(0.012)	(0.007)
Constant	-9.317***		-1.961***		
	(0.650)		(0.750)		
Observations	44,313		22,671		
Pseudo R^2	0.341		0.328		
Time effects' significance	44.76***		97.11***		
	[0.000]		[0.000]		
RESET	0.205		2.476		
	[0.651]		[0.116]		
GOFF1	1.049		1.093		
	[0.306]		[0.296]		
GOFF2	1.294		0.216		
	[0.255]		[0.642]		

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Figures in [ ] indicate *p*-values; Time dummies included but not reported; GOFF1 and GOFF2 are goodness-of-functional-form tests; GDP pc is the per capita gross domestic product of the importer; EU is European Union membership (or not) of the importer; wine produced in period t-1 in importing and exporting countries are represented by Production importer and Production exporter, respectively; Old World is a dummy variable coded 1 if the exporting country is considered an Old World country in wine trade and 0 otherwise; Exch. Rate is the annual average exchange rate between the currencies of importing countries and exporting countries; RTA is a dummy variable coded 1 if there is a regional trade agreement between the exporter and the importer; Distance is the geographical distance between the exporter and the importer; Common language is a dummy variable coded 1 if importer and exporter share the same official language; and Religious proximity is an index measuring common religion beliefs. Source: Authors' computation.

probability of wine of country *i* being imported by a certain country *j* (equation 5); and in column (4) the effect on the magnitude of a non-zero market share of country *i*'s wine in country *j* (equation 6). Column (5) includes the TPE (equation 7). Time effects are considered through yearly dummy variables (omitted due to space considerations), and standard errors account for intra-group correlation.

The results suggest that all parameters estimated in the 1st part of the model (propensity to export) are statistically significant. By observing the APEs, it is also possible to confirm the expected signs for all explanatory variables. It is estimated that the distance between two countries has a negative effect on the probability of wine of an exporting country *i* being imported by a certain country *j*. A depreciation of the exporter's currency in relation to an importer's currency has a negative effect on the export propensity, which following Chaney

(2016) is an expected result in the presence of fixed costs and liquidity constraints. On the other hand, GDP per capita of the importers, wine production of both trade partners, the exporting country being an Old World country, EU membership of importing countries, regional trade agreements established between both countries, and cultural proximity aspects, such as religion and language, present a positive effect.

In the 2nd part of the model most of the covariates have a statistically significant effect, the exceptions being Old World exporting countries, regional trade agreements and religious proximity. The APEs indicate that the market share of wine from an exporting country *i* in a certain country *j* is negatively affected by GDP per capita, wine production, EU membership of importing countries and bilateral distance. However, the market share is positively affected by wine production in the exporting country, common language between trade partners and depreciation of the exporter's currency in relation to an importer's currency.

It is noticeable that only three explanatory variables have APEs with similar signs in both 2nd and 1st parts: distance, wine production in the exporting country, and common language between trading partners. Regarding the other variables, as expected, the effect of depreciation of the exporter's currency becomes positive in the 2nd part, as a result of wine becoming cheaper for importers. The effect of GDP per capita of importing countries goes from positive to negative, confirming the hypothesis that higher purchasing power leads importing countries to search for variety, therefore ranging across more countries to obtain their imports. A negative effect is also caused by higher wine production in importing countries and importer's EU membership, because these variables seems to indicate higher cultural openness to wine consumption but also a taste for variety, which has a negative impact on market shares. Regional trade agreements, religious proximity, and Old World exporting countries have a positive impact on propensity to trade but have not a significant effect on the intensity of trade, meaning that historical, cultural, and commercial relationship are advantages in market entrance.

The TPEs show the effect of each covariate on the magnitude of any market share (including zero) of country *i*'s wine in country *j*. This can be interpreted as a global view of the effect of explanatory variables in both parts of the model. Therefore, the results suggest that, overall, per capita GDP and distance have a negative impact on market shares, while wine production of exporting countries, regional trade agreements, common language, and religious proximity have a positive impact.

As far as it is known, there are no fully comparable results in wine trade literature, as the dependent variable is usually not the market share. The closest comparison can be made with studies focused on determinants of wine exports, in which the dependent variable is usually the value or volume of exports. Most of these works also suggest that bilateral distance has a negative effect on trade (Castillo *et al.* 2016; Dal Bianco *et al.* 2016; Lombardi *et al.* 2016), common language facilitates commercial relationship (Castillo *et al.* 2016; Dal Bianco *et al.* 2016; Lombardi *et al.* 2016; Gouveia *et al.* 2018), regional trade agreements enhance trade (Dascal *et al.* 2002; Castillo *et al.* 2016), and wine production in exporting countries creates an export stimulus (Dascal *et al.* 2002; Agostino and Trivieri 2014; Dal Bianco *et al.* 2016). With regard to the effects estimated for GDP per capita, wine production, and EU membership of importing countries, they are not comparable to such studies due to the difference in the nature of the dependent variable.

4. Conclusion

Competition may be within domestic markets but, in a globalised economy, competitiveness is more and more dependent on the ability of industries to trade at an international level. One of the measures of competitiveness is the export market share, allowing the establishment of direct trading positions. However, when studying international competitiveness it is important to distinguish export intensity from export propensity, as some determinants can present opposite effects in these two respective measures, suggesting that caution should be exercised in policies aiming to improve export propensity because those same policies can lead to deterioration in export intensity, and vice-versa. These aspects call for the use of a 2P-FRM.

It is inferred through the results that strategic decisions of firms in the wine sector should vary according to the objective of the boards. In the case of managerial boards aiming to enter new markets, they should focus on importing countries with high purchasing power, EU membership, and high levels of wine production. These are characteristics of countries with a tradition of wine consumption, which means greater openness to try new wines. Besides that, exploring markets with cultural (religious and linguistic) and commercial (trade agreements) proximity seems to increase trade propensity. On the other hand, corporate decisions should also be concerned about exchange rates and costs underlying distant markets.

A different strategy should be adopted for managerial boards aspiring to increase market shares. In fact, markets with high purchasing power, EU membership, and high levels of wine production become less attractive because their taste for diversification in wine consumption may limit market shares. Therefore, focus should be turned to markets with less tradition of wine consumption, despite the challenge of surpassing greater barriers to entry. This challenge can be overcome, for example, through the establishment of trade agreements and taking advantage of cultural proximity.

The market share is a simple and informative measure of international competitiveness; nevertheless, in future research, it would be interesting to compare different measures to test the robustness of the results. Also, the search for explanatory variables not yet considered in the literature should be done, since their eventual omission can lead to endogeneity and to the subsequent correction of the econometric model. In terms of methodology, including country-pair fixed effects in the 2P-FRM, to treat neglected individual heterogeneity, or considering the Heckman fractional model in development, by Schwiebert (2018), could bring new insights to the nature of international competitiveness in the wine sector.

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Appendix

Table A.1. Descriptive statistics.

Variables	Obs.	Mean	Med.	Std. Dev.	Min	Max
Market share	44313	0.1	0.0	0.1	0.0	1.0
Distance	44313	7823.0	7687.4	4467.6	204.8	19539.5
GDPpc importer	44313	11905.0	3831.5	17791.7	102.6	119225.4
RTA (yes=1; 0 otherwise)	44313	0.2	0.0		0.0	1.0
Exch. rate	44313	23.5	0.3	109.0	0.0	2320.0
EU importer (yes=1; 0 otherwise)	44313	0.1	0.0		0.0	1.0
Production exporter (t-1)	44313	16285.7	10007.0	15483.5	1762.0	60535.0
Production importer (t-1)	44313	1359.8	0.0	6004.3	0.0	60535.0
Old World exporter (yes=1; 0 otherwise)	44313	0.5	0.0		0.0	1.0
Common language (yes=1; 0 otherwise)	44313	0.1	0.0		0.0	1.0
Religious proximity	44313	0.2	0.0	0.2	0.0	1.0

Note: For the binary variables RTA, common language, Old World exporter, and EU membership of the importer the mean represents the percentage of observations equal to one. Source: Authors' computation.

Table A.2. Alternative functional form specifications of the 1st and 2nd parts of 2P-FRM estimations.

Variables	Export propensity			Export intensity		
	Cauchit β_1	Probit β_1	Loglog β_1	Cauchit β_2	Probit β_2	Loglog β_2
GDPpc importer (log)	0.398***	0.200***	0.211***	-0.386***	-0.084***	-0.061***
	(0.034)	(0.017)	(0.018)	(0.086)	(0.016)	(0.012)
EU importer	0.962***	0.641***	0.826***	-0.707	-0.153***	-0.114***
	(0.207)	(0.082)	(0.123)	(0.467)	(0.051)	(0.036)
Production importer (t-1) (log)	0.131***	0.077***	0.078***	-0.167***	-0.026***	-0.018***
	(0.014)	(0.007)	(0.008)	(0.055)	(0.006)	(0.004)
Production exporter (t-1) (log)	0.850***	0.487***	0.595***	1.095***	0.351***	0.274***
	(0.059)	(0.027)	(0.032)	(0.338)	(0.030)	(0.021)
Old World exporter	0.825***	0.460***	0.495***	-0.288	-0.035	-0.026
	(0.099)	(0.048)	(0.051)	(0.456)	(0.056)	(0.039)
Exch. rate (log)	-0.084***	-0.039***	-0.034***	0.086*	0.021***	0.017***
	(0.017)	(0.007)	(0.007)	(0.051)	(0.008)	(0.005)
RTA	0.642***	0.355***	0.461***	0.180	0.038	0.030
	(0.128)	(0.063)	(0.081)	(0.257)	(0.051)	(0.037)
Distance (log)	-0.359***	-0.145***	-0.190***	-1.199***	-0.314***	-0.231***
	(0.067)	(0.037)	(0.040)	(0.138)	(0.027)	(0.021)
Common language	1.490***	0.886***	0.988***	2.399***	0.794***	0.642***
	(0.161)	(0.082)	(0.107)	(0.246)	(0.058)	(0.050)
Religious proximity	1.839***	0.936***	1.132***	-0.128	-0.076	-0.058
	(0.242)	(0.112)	(0.138)	(0.318)	(0.076)	(0.058)
Constant	-9.322***	-5.629***	-5.916***	-0.355	-1.285***	-0.962***
	(0.838)	(0.376)	(0.436)	(3.527)	(0.355)	(0.251)
Observations	44,313	44,313	44,313	22,671	22,671	22,671
Pseudo R^2	0.338	0.341	0.338	0.305	0.325	0.318
Time effects' significance	45.40***	44.97***	52.53***	39.34***	107.03***	116.64***
	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]
RESET	75.262***	16.840***	193.217***	775.004***	19.202***	115.371***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
GOFF1	17.701***	18.047***	n.a.	530.827***	21.229***	n.a.
	[0.000]	[0.000]		[0.000]	[0.000]	
GOFF2	91.675***	7.477***	212.317***	307.573***	19.215***	114.896***
	[0.000]	[0.006]	[0.000]	[0.000]	[0.000]	[0.000]

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Figures in [ ] indicate *p*-values; Time dummies included but not reported; n.a. = not applicable. Source: Authors' computation.

Table A.3. 2P-FRM estimations splitting the sample in pre- and post-financial crisis of 2008.

Variables	Period 1999-2008					Period 2009-2014				
	Export propensity		Export intensity		TPE	Export propensity		Export intensity		TPE
	β_1	APE	β_2	APE		β_1	APE	β_2	APE	
GDP pc importer (log)	0.347***	0.057***	-0.163***	-0.014***	-0.003*	0.345***	0.057***	-0.173***	-0.013***	-0.004**
	(0.029)	(0.004)	(0.032)	(0.003)	(0.001)	(0.035)	(0.005)	(0.038)	(0.003)	(0.002)
EU importer	1.122***	0.184***	-0.248**	-0.021**	0.004	0.939***	0.155***	-0.402***	-0.031***	-0.007
	(0.155)	(0.025)	(0.112)	(0.010)	(0.005)	(0.153)	(0.025)	(0.118)	(0.009)	(0.005)
Production importer (t-1) (log)	0.122***	0.020***	-0.058***	-0.005***	-0.001	0.137***	0.023***	-0.047***	-0.004***	-0.001
	(0.012)	(0.002)	(0.013)	(0.001)	(0.001)	(0.014)	(0.002)	(0.013)	(0.001)	(0.001)
Production exporter (t-1) (log)	0.833***	0.136***	0.610***	0.053***	0.037***	0.828***	0.137***	0.754***	0.058***	0.040***
	(0.049)	(0.007)	(0.066)	(0.006)	(0.003)	(0.053)	(0.008)	(0.075)	(0.006)	(0.003)
Old World exporter	0.739***	0.121***	-0.030	-0.003	0.008	0.815***	0.135***	-0.117	-0.009	0.004
	(0.084)	(0.013)	(0.123)	(0.011)	(0.005)	(0.091)	(0.015)	(0.121)	(0.009)	(0.005)
Exch. rate (log)	-0.058***	-0.010***	0.031*	0.003*	0.001	-0.082***	-0.014***	0.051***	0.004***	0.001*
	(0.013)	(0.002)	(0.017)	(0.001)	(0.001)	(0.014)	(0.002)	(0.017)	(0.001)	(0.001)
RTA	0.620***	0.101***	0.139	0.012	0.014***	0.609***	0.101***	-0.012	-0.001	0.006
	(0.136)	(0.022)	(0.120)	(0.010)	(0.005)	(0.109)	(0.018)	(0.110)	(0.008)	(0.005)
Distance (log)	-0.270***	-0.044***	-0.532***	-0.046***	-0.026***	-0.295***	-0.049***	-0.760***	-0.058***	-0.035***
	(0.061)	(0.010)	(0.057)	(0.005)	(0.003)	(0.067)	(0.011)	(0.062)	(0.005)	(0.003)
Common language	1.457***	0.238***	1.440***	0.125***	0.080***	1.522***	0.251***	1.498***	0.115***	0.078***
	(0.143)	(0.022)	(0.107)	(0.010)	(0.005)	(0.151)	(0.024)	(0.114)	(0.009)	(0.005)
Religious proximity	1.590***	0.260***	-0.167	-0.014	0.013**	1.742***	0.288***	-0.103	-0.008	0.014**
	(0.190)	(0.030)	(0.151)	(0.013)	(0.007)	(0.226)	(0.036)	(0.159)	(0.012)	(0.007)
Constant	-9.409***		-2.240***			-9.285***		-1.641**		
	(0.680)		(0.782)			(0.729)		(0.827)		
Observations	27,408		13,501			16,905		22,671		

Variables	Period 1999-2008					Period 2009-2014				
	Export propensity		Export intensity		TPE	Export propensity		Export intensity		TPE
	β_1	APE	β_2	APE		β_1	APE	β_2	APE	
Pseudo R^2	0.345		0.302			0.333		0.378		
Time effects' significance	28.19***		56.99***			18.44***		40.84***		
	[0.001]		[0.000]			[0.002]		[0.000]		
RESET	0.020		2.044			0.129		0.460		
	[0.888]		[0.153]			[0.719]		[0.497]		
GOFF1	0.026		1.169			0.864		0.117		
	[0.873]		[0.280]			[0.353]		[0.732]		
GOFF2	0.061		0.414			1.145		0.023		
	[0.804]		[0.520]			[0.285]		[0.881]		

Note: Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; Figures in [ ] indicate *p*-values; Time dummies included but not reported.

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Full Research Article

Small-holders perception of sustainability and chain coordination: evidence from Arriba PDO Cocoa in Western Ecuador

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Abstract. Protected Denominations of Origin (PDO) refer to the adoption of producers' voluntary standards to highlight the quality to consumers and improve the socio-economic sustainability of small-holders. Usually, in agricultural circuits, these focus on aspects of production systems and intrinsic features of agricultural raw materials. In agri-food clusters, PDO labels focus globally on market recognition of sensorial elements of farming and agroindustrial products. The study's objective was to analyze socio-economic and governance components to understand the PDO Cocoa Arriba (*Theobroma cacao*) chain and its sustainability to bring forward potential strategies in Ecuador. The information employed comes from the observation of two strings (Arriba PDO and CCN-51) by interviewing 450 respondents. Principal Components Analysis was introduced to contribute with relevant insights. The framework applied accounts with a revision of primary and support activities and coordination mechanisms identification. The study clustered pre-production, production, and post-production tiers. According to the results, Arriba PDO production systems represent a disadvantage for farmers because, from the production point of view, the premium price paid for product certification is debatable. Finally, the enhancement of national regulation to assist chain actors and the stimulus of young producers and associations empowerment is an urgent requirement.

Keywords. Socio-economic, agricultural regulation, family farming, governance structure.

JELCodes. Q18, N56, L17.

1. Introduction

Cocoa (*Theobroma cacao* L.) is a historically strategic agricultural sector in Latin America and constitutes an important crop worldwide for processed and raw material markets (Krauss, 2018)which fail to mention one of the actual key drivers: the need to shore up pro-

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duction in the long term in an embattled sector. Consequently, representations also downplay the need for systemic change, reproducing the power asymmetries they claim to change. The research seeks to establish to what degree public-facing communication differs from underlying priorities in terms of forefronting altruism over necessity, and whether this is problematic for the initiatives' overall outcome. Through semi-structured interviews, focus-group discussions, documentary analysis and participant observation in Latin America and Europe, it reviews relations in two cocoa sustainability initiatives with environmental foci. Crucially, the research establishes a link between representations, underlying priorities and the degree to which they (re. The FAO's latest estimates point out that the world's production of cocoa is more than 4,600,000 tons per year (1,200,000 ha) (Alemagi *et al.*, 2015; FAO, 2018). Ecuador, with an output of 270,000 tons/year, placed ninth in the world ranking producing countries (Saravia-Matus *et al.*, 2020; Williams, 2019). In recent years, the Ecuadorian cocoa chain faced problems such as price fluctuation and low production yield (on average 304 kg/ha) in contrast with direct competitors (e.g., Perú – 634 kg/ha, Colombia- 450 kg/ha) (Kozicka *et al.*, 2018). Besides, its PDO Cocoa is marketed without adequate mechanisms leading to low market performance (Pino *et al.*, 2018). The low coordination and commercialization strategies and biased public policies are unable to differentiate variety-based markets (Marette, 2016; UNDP, 2020). Therefore, specific instruments promoting sustainable chains are vital.

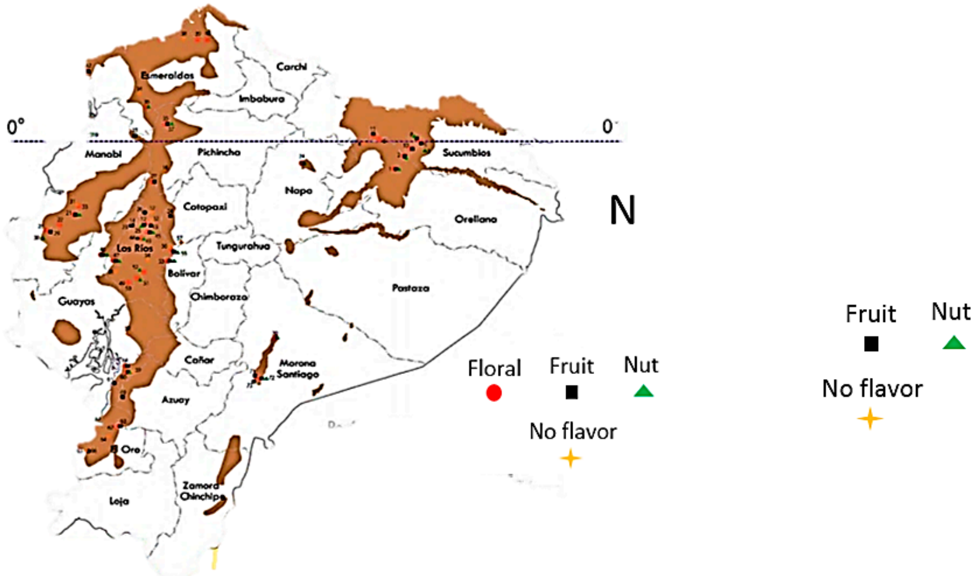
Nevertheless, the Ecuadorian Government, led a process of Cocoa revaluation, through the project "Production and Improvement of the Quality of National Cocoa" (MAG, 2015). The purpose was to improve yields of CCN-51 cloned variety and target national and international markets of PDO cocoa (MAG, 2018). The Ecuadorian PDO cocoa is known as "Cacao Arriba" and characterized by a deep floral-fruity aroma (Benitez, 2018). In 2007, Ecuador submitted the designation of origin (DO) application for Cocoa Arriba, and it was approved in 2013 (IEPI, 2019). Today, Ecuador has the most significant world market share of Cocoa Arriba (63%) (Pino *et al.*, 2018). PDO Arriba production is a clear alternative to promote sustainability and rural development. Various authors argue that studies have only addressed agronomic aspects (Tuesta *et al.*, 2017). An integrative perspective includes a series of variables such as standards application, economic evaluation, and social implications, which underline existing shortcomings (Corsi & Salvioni, 2017). For such reasons, it employs a Principal Components Analysis to reduce a large set by emphasizing variation and bring out strong patterns of social and economic sustainability between Arriba PDO and CCN-51 cocoa chains.

In such a context, the present article aims to contribute by addressing two research questions. The first RQ is *how the Cocoa Arriba PDO chain is different from the CCN-51 cocoa chain in terms of socio-economic performance?* The last RQ is *what kind of governance mechanism does the Cocoa Arriba PDO chain describe, and what sets it apart from the CCN-51 cocoa chain?* As such, the study hopes to further our understanding of the socio-economic sustainability assessment and the relevant insight regarding the cocoa PDO chain. It focused on Los Ríos province since it covers most of the Cocoa Arriba production in Ecuador.

2. Background

Cocoa has been linked to Ecuador's economic performance and is one of the most priced agricultural products on the international market. The geographical structure and biodiver-

Figure 1. Map of geographical area of Arriva cocoa cultivars in Ecuador.



sity of Ecuador allow the cultivation of PDO Arriba cocoa (Figure 1). The production takes place in the equatorial zone at an altitude between cero and 1,200 meters above sea level (Estupiñán, 2018). This zone locates between latitudes 01°27‘06“N and 05°00’56”S and longitude 75°11’49“W to 81°00’40”W (Villamar *et al.*, 2016). Also, it has a humid climate with rainfall of 2,000 to 4,000 mm and slight variations due to the small mountain ranges (ANECACAO, 2017). This native variety is the most appreciated in the international market by representing about 5% of total cocoa production worldwide (MAG, 2018). However, at the local markets, unsuitable mechanisms for the identification of cocoa varieties are largely affecting the chain development. Despite this challenge, Ecuador plays a crucial role because it is responsible for 63% of PDO Arriba cocoa exports at the world level. The responsible actors of PDO Arriba Cocoa production are associations and export enterprises. Besides the PDO Arriba Cocoa, Ecuador grows a cloned variety CCN-51 (Castro Naranjal Collection) for the industry. The agronomic performance of CCN-51 characterized by its resistance to disease and its relatively high productivity.

2.1 Transition of certifications and agricultural policies

The cocoa production certification in Ecuador has a direct connection with the quality of the variety and agriculture practices. In 2008, the Ecuadorian cocoa achieved UTZ (Rainforest Alliance) certification that focuses on attaining ecological agriculture and sustainability principles. In 2012, Organic certifications (USDA / BCS ÖKO) were obtained by cocoa producers, which requires constant revision of agronomic practices. The Fair Trade certification of the Ecuadorian cocoa started to be visible at the end of 2015. Besides, there are national players such as the Ecuadorian Service of Standardization – INEN and the Agency of Phytosanitary Regulation and Control – AGROCALIDAD, focus on certifications related to Good Farming Practices. The lack of regulations of protected denominations of origin – PDO is evident in the subsector of Cocoa (IEPI, 2019; IICA, 2014; Ogus, 1992, 1994).

The International Regulations Agreement on Trade-Related Aspects of Intellectual Property Rights – TRIPS –. R.O. No. 977, June 28/1996 and the Paris Convention for the Protection of Industrial Property. R.O. No. 244, July 29, 1999, supported the process of Cacao Arriba PDO legalization (IICA, 2014). Also, the Andean regulations Normative Decision 486 of the Cartagena Agreement of the Common Regime on Industrial Property R.O. No. 258, February 2, 2001, assisted in recognizing Arriba PDO Cocoa at the international level. Afterward, the Ecuadorian Institute of Intellectual Property (IEPI) established the Cacao Arriba PDO standard (Table 1). "The standard technique allows an activity to take place without any ex-ante control, but the supplier who fails to meet the standards perpetrates an infringement" (Ogus, 1994). The existing standards of Cocoa Arriba are INEN 176 and 177. However, the Inter-American Institute for Cooperation on Agriculture argued this Cocoa Arriba PDO standard requires a specific rule to guarantee the quality of the four types of the Ecuadorian Cacao Arriba (Aidoo & Fromm, 2015).

The Plan for the Agro-industry Development of the Cocoa-Chocolate Chain (PMC Cacao) – 2019 is the most recent supporting policy launched by the Government. It seeks the Ecuadorian leadership as producer and exporter of cocoa and derivatives worldwide. This plan is a joint work between the public and private sectors. Its fundamental pillars are increasing quality and production, promoting national and foreign investment, and strengthening associativity. The plan also highlights the generation of new jobs with a growth rate of 15% per year and public investment - private with an amount of USD 600 million. The European Union – a strategic partner for the project – provides technical assistance in the socio-productive evaluation of the chain. Recent Government reports show an enhancement of productivity thanks to training and agronomic practices. It accounts for a traceability system to support certification efforts and improvement of marketing margins by adequate price incentives. However, the marketing and commercialization of Arriba PDO still present in-

Table 1. Standards of Cacao Arriba PDO and CCN-51.

	Requirement	Unit	Cocoa Arriba					CCN-51
			ASSPS	ASSS	ASS	ASN	ASE	
Fermentation	One hundred of grains	g	135-140	130-135	120-125	110-115	105-110	135-140
	Good	%	75	65	60	44	26	65***
	Slight*	%	10	10	5	10	27	11
	Total	%	85	75	65	54	53	76
Biophysical	Violet	%	10	15	21	25	25	18
	Slaty	%	4	9	12	18	18	5
	Mould	%	1	1	2	3	4	1
Total number of defects (over 500 g)		%	0	0	1	3	4**	1

Source: Ecuadorian Institute of Intellectual Property - IEPI, (2010).

conveniences in price transparency and signaling in the local cocoa market. Therefore, there is a challenge to clarify its socio-economic sustainability and propose integrated strategies aimed to support the development objectives.

3. Methodology

3.1 Study Zone

The present empirical assessment is based on qualitative and quantitative data collected in 2017-2018 from beneficiaries engaged in the project "Production and Improvement of the Quality of National Cocoa." Babahoyo district, located in the coastal region, was selected for several motives. First, this zone is the leader in cocoa production, accounting for 15% of the national share, and with up to 8000 farmers. Second, its agricultural conditions, such as the location above sea level, a temperature between 12 to 25 °C, and climates from tropical humid to semi-humid make a proper ecosystem for cocoa production. Third, producers are ahead of other cocoa zones in adopting sustainability practices to protect the Arriba PDO. Fourth, the Babahoyo location is a dynamic point of Arriba and CCN-51 cocoa trade between producers, intermediaries, processors, and exporters. As such, this study arguably presents a more enriched view of socio-economic performance. The methodology applied includes phases and tools detailed below.

3.2 Questionnaire modeling and sampling

The study segmented producers by using the last Agricultural Census Data. Next, it interviewed professionals from the Ministry of Industries to section the post-production actors. Then, we executed a workshop with stakeholders to select variables from a predetermined list – the list considered social variables to determine the condition of people within the chain (Feschet *et al.*, 2013) we design a pathway for social LCA impact assessment. This pathway may be used to explain or predict the potential impact caused by the modification of one product sector upon the health of a population. The Preston relationship usually is calculated for a cross section of countries. We assess whether the Preston relationship is valid when a single country is considered alone. Drawing from scientific literature regarding development, we define the context where the use of the Preston relationship is justified. We describe the general design of the Preston pathway, using a recalculated (panel based. Production attributes showed aspects related to the agronomic models. Economic factors described sustainability in terms of costing, associativity, and margins (Barrera-Mosquera *et al.*, 2010). The experiment contemplated a one version survey, Cronbach's alpha index validated the questionnaire, and wording was changed to reflect the use of cocoa over other types of products. Each study was pilot-tested with at least three interviewees, who assisted with confusing and ambiguous items, as well as survey layout and flow. The final questionnaire consisted of three major sections, socio-productive and respondents' perceptions of how economic and agronomic issues impact their product performance.

The information obtained from the Ministry of Agriculture-MAG, and Ministry of Production-MIPRO resulted in a list of 450 chain actors. Then, it applied the Sukhatme formula (Sukhatme, 1954), at a 95% confidence level, and employed the variable "number of producers registered by MAG" to target 420 cocoa producers (farmers and cooperative representatives). We contacted post-production actors to participate in the study through interviews and know the information of local cocoa markets. Beforehand, we refined the respondent data set of post-production to eliminate irrelevant remarks. For instance, the study blocked fruit, vegetable, and cereal producers, since they focused on different issues. The final group of participants consisted of 70 post-production participants (cocoa traders and entrepreneurs). Overall, information gathered confirmed a reasonable basis for developing the governance analysis, using the Gereffi Framework (Gereffi *et al.*, 2005). Governance typologies in value chains showed the mechanism for coordinate actors, activities, and stages.

3.3 Fieldwork Database Analysis

The study examined socio-demographic data obtained from surveys by applying statistical descriptions. The descriptive information includes averages for Arriba and CCN-51 respondents, as well as two-population t-tests to examine means' differences. This procedure allowed the characterization of Arriba and CCN-51 chains. The analysis provided a chain mapping by employing the Hawke scheme (Hawkes & Ruel, 2011) and the Dotoli approach (Dotoli *et al.*, 2005). The mapping showed a graphical description of stages, linkages, and connections. Also, it displays vital chain elements, such as value-trajectories, information, and financial flows. Analysis of producer perception used a scale similar to that of Melnyk (Melnyk *et al.*, 2003). Here, the study asked respondents about the relevance of economic and agronomic factors to their crops. The variables were measured on the relative frequency of a five-point scale: 1, extremely irrelevant; 2, irrelevant; 3, neutral; 4, very relevant; and 5, extremely relevant. Then, we employed Principal Component Analysis (PCA) (Jolliffe, 1982) to assess crop constructs (e.g., land tenure, cultivation technique), economic constructs (e.g., costs and yields), and associative measures. The method includes a correlation analysis and standardization of variables. Once orthogonal variables (Z-scores) were obtained from PC analysis, we unified them by using the following expression:

$$Z_{ij} = \frac{x_{ij} - \mu_j}{\sigma_j}$$

where:
x_{ij} z-score of *i* observation, *j* variable
μ_j mean of *j* variable
σ_j standard deviation of *j* variable
Z_{ij} z-score *ij* ajusted

4. Results

4.1 Actors' segmentation and value-chain characterization

Table 2 shows the data provided by the Ministry of Agriculture about the production stage. The data accounted for 10.5 % of cocoa-producing families.

Table 2. Number of producers and cocoa production area.

Province	District	Number of producer families	Area of production (ha)
Los Rios	Babahoyo	1250	1955.5
	Ventanas	750	1040.2
	Vinces	520	840.7

Source: Ministry of Agriculture - MAG, (2015).

4.1.1 Socio-economic Profiles

Table 3 states the socio-demographic profiles of respondents. Most of the CCN-51 chain actors were between 26 and 40 years old (55.3%). The Arriba chain actors were between 41 to 55 years old and represented 65.8% of the respondents. There was a difference concerning the education level, since a high proportion of participants (38.5%), belonging to the CCN-51 chain reported a college education. However, more than 50.3% of Arriba producers only reported a high-school level of education. It is noteworthy that interviewees responded to crop management questions with a high level of knowledge. This aspect is because a large proportion (more than 50%) of producers of both

Table 3. Socio-economic characteristics of cocoa-producing families.

Variable	Proportion			
	Mean	CCN-51	Arriba	p-Value
Gender (n = 250)				
Female		54.0	62.0	
Male		46.0	38.0	
Age (head of family) (n = 250)				
< 18 años	17	2.5	1.4	0.058*
19-25 años	23	14.2	4.2	0.045**
26-40 años	34	55.3	8.2	0.028**
41-55 años	46	17.3	65.8	0.039**
56-65 años	59	9.2	12.2	0.025**
>66 años	68	1.5	8.4	0.437
Education (head of family) (n = 250)				
Primary		13.4	22.5	
Secondary		48.1	50.3	
College		38.5	27.2	
Associativity (households) (n = 250)				
Members		44.9	57.4	
Non-members		55.1	42.6	
Montly household income (n = 250)				
< 700 USD	625	11.4	14.6	0.001***
701-1000 USD	830	19.6	36.2	0.021**
1001-1300 USD	1220	25.2	29.7	0.027**
1301-1700 USD	1580	37.5	17.8	0.032**
>1700 USD	1950	5.5	3.4	0.001***

Note: Difference (p) represents the p-value significance of two population t-test with unequal sample sizes and unequal variances: **** for < 0.001, *** for < 0.01, ** for < 0.05, and * for < 0.1.

chains followed agricultural science programs (Díaz-Montenegro *et al.*, 2018). Regarding monthly income, most of Arriba producers reported a range between 701-1000 USD (36.2%) and CCN-51 producers presented a range between 1301-1700 USD (37.5%).

The average number of household members was 3.6 in both chains, and 63% of respondents reside in Babahoyo district. According to the National Institute of Statistics and Census (INEC, 2010), the average number of members per household is 2.9. (in the coast region). Besides, during 2018, the monthly income was USD 450, on average (Viteri-Salazar *et al.*, 2018). Therefore, the sample showed better representativeness in terms of the average salary of a household member.

4.2 Chain Actors: Influencers/Enablers

Outcomes showed the intervention of chain influencers, such as public entities, advisors, and private agro-centers. These actors aimed to provide a technical assessment to crop management. Peasant families were the first enabler cluster identified and were responsible for channeling the harvest to collection points and wholesalers. The main difference detected was the crop volume of Arriba cocoa, which is 20% of the CCN-51 cocoa volume. Also, exports of dried CCN-51 Cocoa are above 35% of Arriba cocoa exports. However, exports of liquor are the opposite; Arriba liquor exports are 21% greater than CCN-51 liquor. Processors, the second enabler cluster, transform the raw material (dried cocoa) into liquor or paste. Outcomes also detected dealers (third enabler cluster) strategically located in areas close to the plantations. Dealers aimed to link processors and producers, thus dynamizing the trade by transferring the raw material ata the national level. The primary goods sold by the CCN-51 chain are dried cocoa and nibs, while the Arriba chain sold mainly cocoa paste. The Central Bank (external influencer) established the reference prices of liquor and dried-fermented cocoa, based on the International Cocoa Organization–ICCO and the New York Stock Exchange (see Figure 2).

4.3 Chain Roles and resources' streams

Outcomes of the pre-production stage showed the presence of private greenhouses as the main responsible for the supply of seedlings. Due to an increase in rainfall and temperature, respondents pointed out December and May as the best cultivation time. It is noteworthy that crops require a daily shade-period to achieve an optimum level of production. Another essential requirement is surface cleaning – the elimination of pests and weeds, while bush pruning is necessary after the first year of crop life. Producers plan the harvest stage in two phases, the first to collect Arriba cocoa in winter, and the second to harvest CCN-51 cocoa in summer. Producers performed the harvest at intervals of 10 to 15 days. Subsequent stages are fermentation and grain bagging, thanks to the sector's humidity and temperature. Then, producers dried cocoa beans by using solar energy and collection points employed gas dryers.

Roasting and shelling are the main steps in the transformation of cocoa beans. Roasting potentiates aroma and flavor, and husking separates the crust from the almond. The final product is called the nib, which is ground to obtain a thick paste. The paste is refined and later distributed as a semi-processed product. The confectionery sector highly demands the

Figure 2. Monthly averages prices (USD/TM).

Source: New York Stock Exchange, (2019).

cocoa paste, and its price ranges between 10.00 and 15.00 USD/kg in the case of CCN-51 cocoa, and between 13.00 and 20.00 USD/kg in the case of Arriba cocoa. The pastry, baking, and catering sectors are the principal applicants for the refined paste. Production cost ranges between 8.00 and 10.00 USD/kg in the case of CCN-51 cocoa, and between 11.00 and 15.00 USD/kg in the case of Arriba cocoa. At the marketing stage, small intermediaries promote cocoa trading and supply the grain to SMEs and artisans.

Concerning the key streams of resources, outcomes identified two types classified as high and low importance. The cocoa trajectories used the high-relevance streams (HRSs) and connected production, fermentation, and drying activities. The Ecuadorian Standardization Service (INEN) set up a high-quality cocoa standard (see Table 4), which plays an essential role due to local market requirements. The commercialization and transformation are the last HRSs within the chain. Besides, the social, environmental, and political interests of cocoa derivatives are increasing; however, their quality standards, established by INEN through standards 175, 176, and 177, need revision, to boost their market growth (2.2 to 3.5 percent per year).

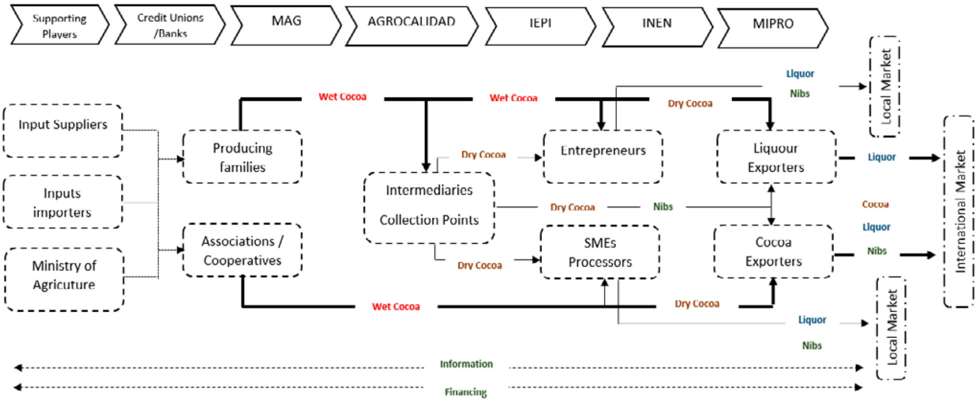
The low-relevance streams (LRSs) connected supporting activities. The first stream was the financial one. Public and private banking entities and credit unions perform financial support. Observations showed financing programs with access to microcredits. Besides, the flow of information was also an essential supporting stream.

Table 4. Biophysical standards of cocoa.

Type of grain	Standard	
	Degree I	Degree II
Moldy	Max. 3%	Max. 4%
Slaty	Max. 3%	Max. 8%
Affection by insects	Máx. in total 3%	Máx. in total 6%

Source: Ecuadorian Standardization Service - INEN, (2006).

Figure 3. Mapping of the Cocoa Chain at Babahoyo District.



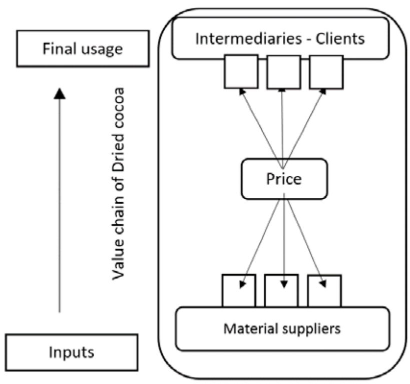
Technical and marketing information streams were in high demand from actors. Ministry of Agriculture and the Institute of Agricultural Research (INIAP) were the leading providers. However, there were also private organizations focused on disseminating aspects of prices and marketing opportunities. Figure 3 shows the mapping of all the components contained herein.

4.4 Chain Coordination

The study examined the coordination mechanism, information coding, the complexity of the inter-firm information transfer, and the level of competence of actors. Therefore outcomes are as follows:

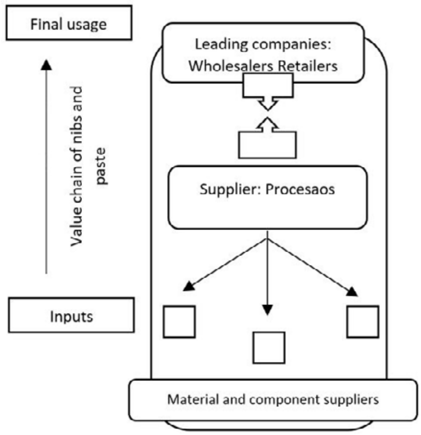
1. Market coordination. The CCN-51 chain characterized by governing bodies, such as farmers (suppliers) and dealers (intermediaries). Repetitive transactions easily codified within exchange environments, such as local markets, are the main feature. The most common district markets close to Babahoyo are Quevedo, Ambato, and Guayaquil. Cash payments or contracts with short credit periods, no more than eight days, were the primary business coordination mechanisms (See Figure 4).
2. Modular coordination. The Arriba chain showed a setting whose transactions codified a relatively high level of complexity. The study observed a sort of power market imposed by governing bodies, such as processors and dealers. These actors set product specifications, credit periods, and buying prices through contracts. Besides,

Figure 4. Coordination mechanism at CCN-51 cacao chain.



liquor and nibs processors acquired generic machinery, to reduce the risk of investment. The most common acquisitions are refiners, molders, and peelers. The relationships between actors is based on local and global market information and technical procedures (See Figure 5).

Figure 5. Governance mechanism at Arriba chain.



4.5 Producer Perception and Comparative Analysis

The experiment examined the cocoa producers' performance in both chains, to elucidate socio-economic and production aspects. We applied a Principal Components Analysis on the 12 primary variables. The details of the variables studied are in Table 5. The components (KMO = 0.818, Bartlett's test $\chi 2$ sig. 0.000) arose with values greater than 1, satisfactorily explaining 70.22% of the variance.

Results in Table 5 reveal that for producers' performance evaluation, plant production factors are the most relevant. Outcomes classified this component as agronomic. Variables in the agronomic part were cocoa variety, land tenure, cultivation technique, number of crops, and post-harvest practices. Cocoa variety is a factor that had the most impact on producer performance. Thus, we performed a PCA by producer group, i.e., Arriba and CCN-51, to investigate differences between both chains.

In the case of Cocoa Arriba producers, the first component is noteworthy on account of its impact. The variables included land tenure, cultivation technique, associativity, and post-harvest practices, i.e., factors inherent to crop development (see Table 6). Most of the variables represented strategic information for excellent production performance. However, it is essential to emphasize that the results presented the associative variable as a crucial aspect for this group of producers. Besides, the price variable captured little interest, possibly because the cocoa market is expanding its quotas and business opportunities (Scherer & Ross, 1990).

In the case of Cocoa CCN-51 producers, the second component had the highest score. The variables included production cost, financing, yields, cocoa acreage, and acreage, i.e., factors inherent to economic and management planning (see Table 7). Most of the variables represented strategic financial performance. However, the results showed the associative variable as having little impact on producers' perception. The price variable also had little effect, possibly because international markets have already established the price of CCN-51.

Finally, Figure 6A distinguished two distinct segments – non-association members and associated members – by considering agronomic and financial components. We observed that most Cocoa Arriba producers opted to be part of associations. Respondents pointed out benefits, such as reducing economic risk, because representatives addressed production by following strategies formulated by consensus. In Figure 6B, the interpretation is differ-

Table 5. Producers' perception of the relative importance of productive performance aspects.

Variable	Relative frecuency					Aggregate score	
	Fully no relevant	No relevant	Neutral	Very relevant	Extremely relevant	Mean	S.D
Acreage	2.2	1.5	14.3	38.1	43.9	4.31	0.85
Cocoa acreage	2.1	3.7	19.2	40.3	34.6	4.27	0.77
Production cost	2.5	4.5	28.2	38.9	25.9	3.69	0.89
Yields	3.1	4.9	33.7	36.2	22.1	3.55	0.92
Financing	2.5	5.9	38.1	32.5	21.0	3.69	0.91
Land tenure	2.9	5.7	40.2	34.9	16.3	3.62	0.88
Price	1.5	3.2	38.7	36.5	20.1	3.66	0.91
Cocoa variety	1.3	9.8	32.6	38.2	18.1	3.63	0.95
Cultivation technique	9.4	12.5	26.3	30.7	21.1	3.58	2.47
Additional crops	4.5	10.2	31.8	34.3	19.2	3.58	0.77
Post harvest practices	2.5	19.7	38.1	25.9	13.8	2.98	0.84
Associativity	18.2	22.2	30.2	18.1	11.3	2.74	1.35

Table 6. Matrix of extracted components from PCA analysis of Arriba cocoa producers.

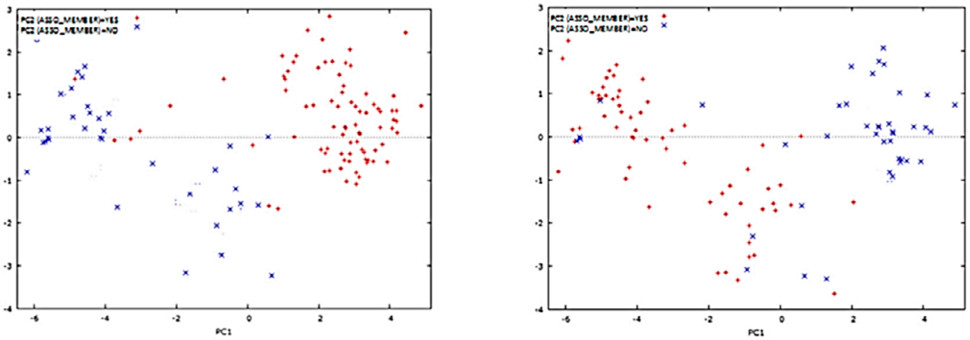
		Component		
		1	2	3
Variable	Land tenure	.961		
	Cultivation technique	.855		
	Associativity	.827		
	Postharvest practices	.818		
	Acreage		.875	
	Production cost		.862	
	Cocoa acreage		.795	
	Yields		.761	
	Financing		.733	
	Additional crops			.725
	Price			.772
	Eigenvalue	4.422	1.524	1.102
Statistical factors	Variance %	38.471	15.218	16.531
	Cumulative variance %	38.471	53.689	70.220
	Cronbach alpha	0.891	0.895	0.758
	Mean	3.11	2.53	2.89

ent because CCN-51 producers did not tend to be part of associations; they opted to make independent decisions.

Table 7. Matrix of extracted components from PCA analysis of CCN-51 cocoa producers.

		Component matrix		
		1	2	3
Variable	Additional crops	.824		
	Cultivation technique	.811		
	Land tenure	.752		
	Postharvest practices	.623		
	Production cost		.951	
	Financing		.983	
	Yields		.845	
	Cocoa acreage		.839	
	Acreage		.712	
	Price			.753
	Associativity			.694
	Eigenvalue	4.277	1.671	1.215
Statistical factors	Variance %	35.522	18.196	14.112
	Cumulative variance %	35.522	53.718	67.830
	Cronbach alpha	0.866	0.899	0.761
	Mean	3.05	2.73	2.71

Figure 6. (A) Scatter plot of Arriba producers and associativity; (B) Scatter plot of CCN-51 producers and associativity.



(A) (B)

5. Discussion and Conclusions

Improving the sustainability performance of agri-food circuits from the socio-economic point of view implicates structural changes. Cocoa producers, traders, processors, and distributors are agri-food sub-clusters and have responded to rural development problems, associativity, and cost-efficiency. Market opportunities, together with certification, such as

PDOs and supporting policies such as the Plan for the Agro-industry Development of the Cocoa-Chocolate Chain, look for synergy to supporting agricultural activities. Environmental aspects related to soil conditions of crops, pest-management plans, and deforestation practices have been examined extensively. However, social and economic factors have received little attention. This paper aimed to provide an initial comparison between two different chains, CCN-51, and Arriba PDO. The emphasis was on highlighting the socio-economic conditions and their effect on the sustainability of the PDO chain, which is widely recognized worldwide. While two research questions tackled this aim, the results showed marked differences between both cocoa chains. We also faced a scarcity of indicators of a holistic sustainability assessment. Such findings highlight the complexity of evaluating sustainability conditions, encourage future discussion, and motivate frameworks for assessing the cocoa chain comprehensively.

Results suggest that the Arriba PDO chain shows a disadvantage in the age profile of its population, which constitutes a possible threat. The education level of Arriba workers, as well as their associativity, have fundamental weaknesses. Regarding academic formation, actors required an integrated perspective to make decisions effectively. Likewise, differences in monthly income pointed out a drawback for Arriba cocoa PDO producers. Thus, our findings conclude with the need for public intervention aimed to promote training programs on topics such as sustainable farm management and incentives to linkage young producers. Most public bodies' response has focused on production and market price monitoring. Instead, private institutions, such as ANECACAO has led various projects aimed to coach producers on cultivation techniques and the use of technology in crops (ANECACAO, 2017).

Furthermore, public entities engaged in manage local and international market intelligence systems have focused on on-demand detection. For instance, PRO ECUADOR is a public institution aimed to connect buyers and sellers of high-value products (PROECUADOR, 2018). Also, it provides webinars on specific topics such as market strategy and market niches information. However, the effectiveness of market participation requires a profound accompaniment aimed to differentiate, recognize, and re-evaluate Arriba PDO at the local and international levels to address cost efficiency and improve margins for producers, SMEs, and entrepreneurs. In 2016, FEDECADE, a private association of cocoa producers, performed a national study investigating the Arriba PDO cocoa market (IICA, 2010). It concluded that small-holders do not possess sufficient resources to invest in promoting the Arriba PDO cocoa and derivatives.

Based on these events, the government launched the public policy Plan for the Agro-industry Development of the Cocoa-Chocolate Chain (PMC Cacao) – 2019. With the aim for underpinning both circuits, CCN-51, and Arriba (MAG, 2019). CCN-51 cocoa was assessed for mass markets and the industrialization of comparable products, such as nibs, cocoa powder, and degreased chocolate for toppings, among others. Cocoa Arriba is a good whose sensory potential is exploited in products with high quality and differentiation, that is, in exclusive market segments.

Consequently, we confirm that the execution by public bodies of equal strategies for both chains in terms of market orientation is a severe error. Thus, coordination mechanisms play a crucial role in correcting the affection at the market level and improving the PDO chain performance. The PDO chain showed little interest in the price mechanism, since the world market is expanding, and actors are looking for a significant transition towards a sustainable chain. The modular governability of the PDO chain shows the need for design and strengthening precise information flows that aim to achieve high value-added consumer goods. We believe that the market for processed Cocoa Arriba-based goods has full reception at the local level, and even more so in global markets (IICA, 2014). Europe, Asia, and North America are markets which demand this type of good. Further, findings concluded that future research on integrated ecological and institutional practices within the multi-level approach is necessary. Future studies must focus on different labor and agricultural practice regulations and policies to monitor their significant role in the adoption of sustainable models.

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Full Research Article

Spatial distribution of organic farms and territorial context: An application to an Italian rural region

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Abstract. Organic farming is increasingly promoted and supported at several levels for its capability of producing safe food and public goods. It can give an important contribution to attenuating the environmental pressure generated by conventional agriculture. This paper analyses possible determinants of the spatial distribution of organic farms in a rural region of Italy, characterised by several environmental issues. Towards this aim, a quasi-Poisson hierarchical generalised linear model with mixed effects is adopted. Results indicate that there is spatial correlation and that the distribution of organic farming is related to socio-economic, environmental and political factors. In particular, they show that public support could have favoured the spreading of organic farming where there are more problems of erosion but far from the areas where there is intensive agriculture.

Keywords. Organic farming, environmental pressures, rural development policy, hierarchical generalised linear mixed model.

JEL Codes. C25, Q18, Q56.

1. Introduction

Organic farming is defined as an overall system of farm management and food production combining best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method consistent with consumer preferences for products produced using natural substances and processes (Council of European Union, 2007). Organic farming has been acquiring growing importance because of the dual role it plays: it provides quality and safe food in response to an increasing consumer demand and, at the same time, it produces public goods contributing to the protection of the environment, animal welfare and rural development.

In consideration of the important contribution of organic farming, better understanding how this phenomenon develops and which factors affect its spatial distribution can be diriment for policy makers in planning strategies pursuing objectives of sustainable development in rural areas.

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In this respect, there is a growing body of literature about the identification of factors that influence spatial patterns of organic farms. Several studies have shown that the adoption of organic farming is spatially clustered (Nyblom *et al.*, 2003; Parker and Munroe, 2007; Lewis *et al.*, 2011; Schmidtner *et al.*, 2012; Bjørkhaug and Blekesaune, 2013; Taus *et al.*, 2013; Wollni and Andersson, 2014). Moreover, a number of determinants explaining the territorial distribution of organic farming have been highlighted. They are, in particular, the neighbouring effects connected with social influence and learning (Nyblom *et al.*, 2003; Lewis *et al.*, 2011), access to information (Frederiksen and Langer, 2004; Genius *et al.*, 2006; Läpple and van Rensburg, 2011), existing agricultural systems (Häring *et al.*, 2004), characteristics of the agricultural landscape (Gabriel *et al.*, 2009; Schmidtner *et al.*, 2012) and proximity to markets and urban areas (Häring *et al.*, 2004; Koesling *et al.*, 2008). Another important factor that can justify different concentrations and development paths of organic farms between areas and regions is represented by public support (Nyblom *et al.*, 2003; Frederiksen and Langer, 2004). In Europe, the most important policy in favour of organic farming is represented by the Common Agricultural Policy (CAP), which, by means of the Rural Development Policy (RDP), provides incentives that are aimed at compensating farmers for additional costs and income foregone deriving from the conversion or the maintenance of organic farming practices (EU Regulation No. 1305/2013).

The main objective of this paper is to analyse the determinants of the spatial distribution of organic farms in a rural region located in Central Italy. Firstly, a Poisson regression model is adopted to analyse the effects of several social, economic, environmental and political factors on the territorial distribution of organic farms. The neighbourhood influence is then assessed to verify the appropriateness of a spatial model. Thus, a quasi-Poisson hierarchical generalized linear mixed (HGLM) model is applied, allowing for under- overdispersion and including a spatially autocorrelated random effect. Poisson regression models are applied by representing the regional territory as a regular grid of uniform cells and considering the number of organic farms localized in each cell as a response variable.

This paper adds in the literature concerning the identification and the assessment of contextual factors explaining the spatial distribution of organic farms. The focus is thus territorial rather than the individual farm. The context can play an important role in terms of increasing returns to adoption due to the economies of scale associated with the concentration of organic farms. These economies include, for instance, formal and informal networks of organic farmers, technical support structures and downstream structuring (Allaire *et al.*, 2015). They are the result of shared needs and collective capabilities derived from past experience by all organic farms. If this experience is transmitted to neighbouring territories, it generates spatial autocorrelation, which goes beyond individual behaviours and specific territorial determinants. The main contribution of this paper is both territorial and methodological. Firstly, it analyses a regional area, i.e. the Marche region, which exhibits interesting peculiarities. This region presents very diverse characteristics from the coast to the Apennine mountains and is therefore representative of the high heterogeneity of the Italian territory. Moreover, it is characterised by significant phenomena of erosion and negative environmental effects generated by intensive farming and related to a high specialization in arable farming (Rusco *et al.*, 2008). In this context, organic farming could therefore be very helpful in reducing the environmental impact generated by agriculture. From a methodological standpoint, rasterized data are used to determine the influence of territorial factors on a discrete variable, represented by the concentration of organic farms. Although rasters are most commonly used to represent continuous data, such as temperature and elevation values, they are often used to represent categorial or discrete data as well (Pingel, 2018). Rasterization, based on a common spatial reference, allows us to use an heterogenous set of statistical data, composed of discrete and continuous variables, and available in different formats and at different resolutions. To this aim, various techniques are adopted to rescale data to the same spatial unit. In comparison with traditional approaches based on the use of administrative borders, gridded data allow a better analysis of causes and effects of socio-economic and environmental phenomena (Eurostat, 2016). Moreover, rasterization of farms, i.e. their aggregation within cells, is one of the possible statistical-disclosure-control techniques to tackle the issue of ensuring anonymity in using micro-data (United Nations, 2007), which is instead potentially present in research works at a farm level and based on the use of point data (i.e. Läpple and Kelley, 2015)

In literature, there are a few studies that analyse the influence of territorial factors, rather than those at a farm level, on the distribution of organic farms through spatial econometric models for count data. For instance, Gabriel *et al.* (2009) use a raster approach based on a 10-km grid to investigate the spatial distribution of organic farms in England and analyse the degree to which environmental and socio-economic factors correlate with their distribution. To assess the effects of covariates, they adopt a hurdle model (Cragg, 1971). They analyse the presence/absence of organic farms using a generalized linear model (GLM) with binomial errors, and the concentration of organic farming using a GLM with Gaussian errors. Spatial information is incorporated by fitting spatial eigenvector mapping into the binomial model and by performing a spatial autoregressive (SAR) model for the Gaussian model. More recently, Allaire *et al.* (2015) analyse the influence of territorial context on the diffusion of organic farming in France, measured by the number of beneficiaries of aid for conversion to organic farming (COF) existing in micro-territories at a NUTS-4 scale. A hurdle model, composed of a spatial probit model and a non-spatial zero-truncated negative binomial regression, is applied to assess both the extent of the contracting of COF aid and its local intensity. Hurdle models, as well as zero-inflated Poisson (ZIP) models (Lambert, 1992) and their variants, are commonly used to handle the overdispersion in the response variable generated by a high number of zeros. These models are based on some theoretical assumptions. They assume that either zero observations have different origins (ZIP models) or zeros and positive counts are generated by different processes (hurdle models). These models are also restricted to overdispersion, therefore excluding the possibility of underdispersion, which is another issue, even if less frequent, that may occur. Moreover, in the cases where spatial effects are not considered, they fail in handling a further source of overdispersion generated by spatial aggregation, which increases the probability of observing zeros. A more flexible model is the quasi-Poisson HGLM model. The latter does not introduce any assumption about the distribution of zeros. Moreover, it can handle both under- and overdispersion in the response variable, generated by excessive zeros and spatial dependence. This kind of model has been recently used by Lee *et al.* (2016) in the ecology field, showing its superiority in spatial prediction in comparison with zero-inflated and hurdle models. To our knowledge, it has not yet been used in agricultural studies, in particular in the field of organic farming. Compared with existing research, a further novelty is therefore the analysis of the influence of territorial factors on the concentration of organic farms using raster data in conjunction with a quasi-Poisson HGLM model for jointly handling dispersion in both directions and spatial dependence.

The reminder of this paper is organized as follows. Section 2 is devoted to illustrating the area under study, the variables and the dataset used, and the spatial econometric model adopted. Sections 3 and 4 present and discuss the main results, also providing some policy recommendations. Final section concludes.

2. Materials and methods

2.1 The area under study

The area analysed in this study is the Marche, an Italian rural region. It is located in the Central-Eastern part of Italy and has an area of 9.7 thousand km^2, equivalent to about 3% of the national territory. Most of the territory is mountainous or hilly. The annual average temperature varies from 5 to 14 °C. In the coastal strip and middle hill, the climate is Mediterranean. It gradually turns into sub-Mediterranean moving inward, while it is similar to the oceanic one in the mountains although Mediterranean influences are still present. The average annual precipitation is 700 to 1,400 mm as we move from the coast towards mountain areas.

Agriculture is particularly important in the region from a territorial standpoint. The share of total surface managed by farms amount to 68%, against a national average of 57%. This reveals the importance of regional agriculture in managing natural resources and, thus, in affecting the overall quality of the environment.

The Marche region is characterized by a marked specialization in arable crops. Based on 2013 data (ISTAT, 2015), regional farms with arable crops are more than 37 thousand units, i.e. 90% of total farms, and cultivate over 361 thousand hectares, equivalent to 81% of regional utilized agricultural area (UAA), which is by far higher than the national share (55%). However, this strong specialization, which is also associated with an intensive use of inputs and extensive application of mechanization, raises some concerns about the high pressure that agriculture can potentially exert on the environment, in consideration of the morphologic characteristics of the region (Bonfiglio *et al.*, 2017). In fact, about 90% of the agricultural area is subject to erosion with annual values of eroded soil ranging between 5 and 20 tons/ha. This phenomenon is due to the natural morphology of the territory and is quite significant in terms of geographical coverage. Intensive farming aggravates this problem and, in addition, produces pollution. The nitrate vulnerable zones cover an area corresponding to 11% of the territory, approximately 21% of total UAA. These zones fall into major regional river basins and involve both areas around river courses and the regional coastal strip (Regione Marche, 2015a).

In this context, organic farming could be one of the possible options to attenuate the environmental pressure generated by agriculture, thanks to the relevant environmental benefits. In particular, organic farming can help to preserve soil (Arnhold *et al.*, 2014; Reeve *et al.*, 2016) and reduce water, soil and air pollution by banning the use of chemical pesticides and synthetic fertilizers (Jouzi *et al.*, 2017).

Besides an increasing demand for organic products, the constant rise of organic farming has been significantly affected by policy support (Sanders *et al.*, 2011). In Italy, as in other European Member States, the most important policy instrument supporting organic farming is the RDP.[1] In the 2007-2013 programming period, measure 214 about agri-environmental payments (Reg. EC No 1698/2005) has been introduced to encourage the introduction and the maintenance of organic production. In the 2014-2020 programming period, it has been replaced by measure 11 (Reg. EC No 1305/2013). One of the main differences between the two frameworks is that, while measure 214 financed several agricultural production methods compatible with the protection and the improvement of the environment[2], measure 11 specifically supports organic farming.

Organic sector is still growing in Italy (SINAB, 2001,2008,2015). From 2007 to 2014, the number of organic operators and the agricultural area managed organically have increased by 21% and 10%, respectively. However, this expansion has slowed down in the last years since the relevant measure has exerted lower appeal. The reasons for this relate to relatively low incentives in favour of organic farming, high disparity between payment levels at a regional level and return to conventional farming, determined by sudden price increases in some commodities and more incentivizing schemes supported by measure 214, such as integrated farming (Zaccarini Bonelli, 2011).

From a regional point of view, in 2014, the Marche region was the eighth Italian region in terms of importance. There were 2,187 organic operators (4% of total organic operators) with an agricultural area of about 57 thousand ha (4% of total area). Relative to 2013 total UAA (ISTAT, 2015), the share of organic area was 13%, slightly higher than the Italian average, amounting to 11%. After experiencing a significant phase of expansion in the early 2000s (the number of operators has grown by over 60% from 2000 to 2007), the regional organic sector has been involved by a continuous process of decline: from 2007 to 2014, organic operators have decreased by 23% and the agricultural area used for producing organic products has diminished by 44%. In addition, from 2007 to 2013, the share of organic area in relation to total UAA (ISTAT, 2008,2015) has decreased by about 8% while the national one has increased, even if slightly, passing from 9% to 11%. Regarding policy application, according to 2015 data about financial implementation (Regione Marche, 2016a), the Managing Authority of the Marche region allocated €108.8 million (of which €49.6 million represented by EAFRD contribution) to measure 214 for the 2007-2013 programming period, equivalent to 22.5% of total RDP expenditure.

2.2 The variables analysed

The count (dependent) variable used is the number of organic farms operating in the Marche region. As regards potential determinants, a number of variables that could affect the distribution of organic farming are investigated. They refer to the following aspects; existing farming system; land use; environmental characteristics; demographic and social characteristics; policy.

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[1] In addition to the RDP, there exist other policy instruments in favour of organic farming, which are not considered here, such as Article 68 of Regulation EC No 73/2009, contribution to producer organisations of the fruit and vegetable sector based on Regulation EC No 1234/2007 and further national/regional support outside the CAP. For a wider discussion about these policy tools, see for instance Sanders *et al.* (2011).

[2] In the case of the Marche region, five actions were financed by measure 214 of the 2007-2013 RDP: a) integrated production; b) organic farming; c) protection and improvement of soil; d) maintenance of local endangered varieties and breeds; e) better management of permanent pastures (Regione Marche, 2015a).

Farming system is described by the number of total farms (this serves as an exposure; see the methodological section for details), the share of the agricultural area used for arable crops, UAA per farm, labour units per hectare and the share of young farmers. Land use is described by the percentage of urban and natural areas. The environmental characteristics considered are altimetry, soil fertility and erosion. Altimetry is measured as the natural logarithm of meters above the sea level. Soil fertility is modelled using data about the percentage of soil organic matter. Erosion is approximated by the quantity of tons of soil per hectare, which are lost due to surface water flows. Demographic and social factors are represented by the shares of resident population aged 20-39 (young population) and 40-64 (adult population) and by the proportions of population with higher education (high school and university). Finally, policy is represented by the total amount of public subsidies per hectare of agricultural area.

The choice of determinants takes account of different aspects such as potential benefits of organic farming, the context considered, and the variables investigated in studies concerning organic sector. Specifically, it is based on the following considerations. Given its potential contribution to the environment, organic farming is expected to be more concentrated in territories of the Marche region where there are or there might be more critically environmental issues, i.e. where there are higher levels of erosion and lower levels of soil fertility. This would be consistent with previous research showing a higher presence of organic farms where soil is less fertile and the levels of erosion are higher (Lewis *et al.*, 2011; Gabriel *et al.*, 2009; Wollni and Andersson, 2014; Paudel and Thapa, 2004). Moreover, organic farming should be less concentrated in areas where its environmental contribution is lower because of the prevalence of natural elements, i.e. where there is a higher share of natural areas. The altimetric distribution of organic farms may also be important from an environmental point of view. In the medium-high hills of the Marche region, organic farming can prevent from phenomena of landslides and leaching, thus preserving soil integrity, while, in flatter areas, it can reduce the quantity of pollutants produced by agriculture. With reference to the existing farming system, organic farming can contribute to reducing the environmental pressure exerted by intensive agriculture. Therefore, we expect that organic farming is more concentrated where there is a higher soil exploitation, i.e. in areas characterized by higher levels of mechanization, thus a lower use of labour, and a higher specialization in mechanizable crops, such as arable crops. However, the adoption of organic farming can significantly depend on the relevant costs. In this respect, Häring *et al.* (2004) have pointed out that the conversion to organic farming is more convenient for farms using practices that are less intensive in the use of mechanization. In this case, in contrast with our expectations, we would have a higher presence where the contribution of organic farming to the environment is lower. Regarding further characteristics of farms, Läpple and van Rensburg (2011) have shown that the adoption of organic farming is more probable among smaller and younger farmers. This can be justified by the economic opportunities, in terms of relatively higher prices and public subsidies, which organic farming can give to new entrants and, in general, to farms that are too small to compete on the market. The result would be a higher concentration of organic farms in locations where there is a higher percentage of young farmers and small-sized farms. However, regarding farm size, Pietola and Lansink (2001) have shown that farmers who have large land areas are more likely to switch to organic farming since they have more possibilities of applying extensive farming technologies. In line with this result, Koesling *et al.* (2008) have found that the probability that a farmer will produce organically rather than conventionally increases if the farmer has more farmland. As regards socio-demographic characteristics, Wier *et al.* (2008) have shown that urbanization, education and population age play an important role in consumer choices. In particular, medium and long education increases the propensity to purchase organic foods. This propensity is also higher in more adult population and where the levels of urbanization are higher. Looking at the supply side, studies, such as those by Häring *et al.* (2004) and Koesling *et al.* (2008), have shown that organic farms, for which direct marketing is particularly important, tend to localize close to urban areas, because they would have an easier access to consumers. If these results were confirmed, we should find that organic farms are mostly located where the percentage of urban areas as well as the share of population aged 40-64 and with higher education are higher. Finally, policy may be another important factor to be considered since it can incentivise the spreading of organic farms by compensating higher costs or lower income resulting from organic management (Sanders *et al.*, 2011).

2.3 The dataset used

Data come from several sources and are available at a different geographical detail, i.e. points, irregular polygons and grids with different resolutions. For this reason, they are rescaled to the same territorial unit, represented by regular grids[3] composed of uniform cells.[4]

Specifically, data about organic farms refer to 2014 and come from the national register of organic operators. Organic farms are both those who are already organic and those who are converting to organic farming. For every farm, there is information about the relevant headquarter address, which is used to identify the exact geographical position and localize farms within cells. Total number of organic farms per cell is thus obtained as a sum of the organic farms localized in each cell.[5] Overall, in 2014, organic farms operating in the Marche region and enrolled in the national register amounted to 2,160 units.[6]

2010 agricultural census is used to retrieve information about total farms and the relevant data about UAA and the age of farmers. Coordinates of the firm site or, alternatively, the relevant address are used to localize farms within each cell. This allows us to derive total number of farms and of young farmers, who are less than 40 years old, existing in each cell.

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[3] The methodology used for dividing the territory into grid cells is based on the INSPIRE Equal Area Grid system (INSPIRE, 2014). Spatial representation is defined by a specific system of geographical coordinates (ETRS89-LAEA) that can be used as a common reference for different sources and studies. According to this system, cell sides should have a length included between one metre and 100 km with multiples of 10.

[4] It should be cleared that not all cells are of regular size. In fact, the shape of the cells located on administrative borders of the region is adjusted in such a way to correctly represent the regional territory.

[5] Data on the agricultural area used by organic farms are also available. However, they are the sum of hectares that can be partly positioned in cells different from those where organic farms are localized. Of these hectares, the exact localization, which is necessary for georeferencing, is unknown. Moreover, for farms which are converting into organic farming, information about the area in conversion towards organic is not available. Accordingly, data about the agricultural area of organic farms cannot be used.

[6] In allocating farms among cells based on their headquarter address, it can occur that some organic farms fall in cells where there are not agricultural producers according to the agricultural census or there is not agricultural land according to 2012 Corine Land Cover. For instance, in the case of a grid of 3-km size, there are 7 farms of this kind. This happens when headquarters do not correspond with operational sites. Since removing these farms can produce biased estimates, they have been reallocated in the neighbouring cells where there are agricultural producers and land using the k-nearest neighbours algorithm (package spdep version 1.1.3 in R3.5.3).

UAA per farm is calculated by dividing total UAA of farms located in each cell by the number of farms. The share of young farmers is obtained by dividing the number of young farmers by total farms falling into each cell.

2012-2014 data from Italian Farm Accountancy Data Network (FADN) are used to estimate labour intensity. Specifically, regional average ratios of labour units to UAA, differentiated by land use and five altimetric zones, are firstly calculated using FADN. These coefficients are multiplied by the shares of agricultural area present in each cell, taking account of different uses according to 2012 Corine Land Cover and the altimetric zone of the cell. The sum of labour units distinguished by land use represents the total labour units employed in each cell. Dividing this sum by total agricultural area, labour units per hectare are obtained.

Information about land use comes from 2012 Corine Land Cover and is available at a 100-metre resolution, i.e., one-hectare area. The database classifies land in five main classes, of which classes "Artificial surfaces" and "Agricultural areas" are used to identify urban and agricultural areas, respectively. Sub-classes "Shrub and/or herbaceous vegetation associations" and "Open spaces with little or no vegetation" within class "Forest and seminatural areas" are instead employed to define natural areas. Urban, agricultural and natural areas are obtained by summing the relevant hectares recorded in the dataset and falling into each cell. The shares of urban and natural areas are calculated as ratios of the corresponding hectares to total area, obtained as a sum of hectares belonging to all classes. Sub-class "Arable land" within "Agricultural areas" is used to derive arable land and calculate the relevant share, obtained by dividing arable land by the total area attributed to each cell. All sub-classes within "Agricultural areas", including "Arable land", "Permanent crops", "Pastures" and "Heterogeneous agricultural areas", are used to estimate labour intensity (see above).

Data concerning soil erosion come from the 2015 European dataset "Soil Loss by Water Erosion in Europe", which offers detailed information on soil erosion by water in 2010 for the European Union at a resolution of 100 metres (Panagos *et al.*, 2015). Data on erosion are available as tonnes per hectare.

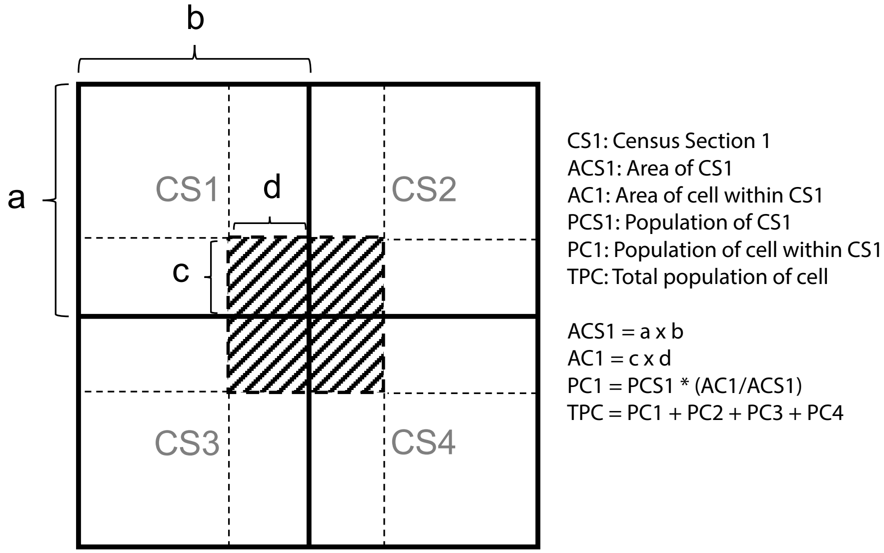
Data related to soil organic matter are from the EFSA Spatial Data Version 1.1 and are available at a resolution of 1,000 metres (Hiederer, 2012). The dataset is composed of several layers, of which that relevant to organic matter concentrations expressed as percentages is used. Shares are calculated from the map of topsoil organic carbon by applying a factor of 1.72. This factor assumes an average organic carbon content of organic matter of 58%.

Information about altimetry, expressed in meters, is retrieved from Shuttle Radar Topography Mission dataset, managed by the U.S. Geological Survey agency. In particular, we use digital elevation data published in 2014 with a resolution of 3 arc-second for global coverage, corresponding to a spatial resolution of about 90 meters.

Levels of erosion, organic matter concentrations and altimetry of each cell are estimated by summing the respective levels relevant to the areas falling into each cell and dividing these sums by the number of areas that belong to the cell, so obtaining an average level of erosion, an average percentage of organic matter concentration and average altimetry for every cell.

Data about resident population, distinguished by age and level of education, come from 2011 population census and is available by census section, which represents the minimum territorial unit of a given municipality on which the census survey is based. Spatially, it is represented by an irregular polygon. The sum of all census sections gives the entire regional territory. The polygons corresponding to census sections are firstly cut using regular grids

Figure 1. Subdivision of census sections into regular cells and estimation of the population of a given cell (square with diagonal stripes) belonging to several census sections.



Note: for the sake of simplicity, census sections are supposed to be represented by regular polygons

in order to quantify the area falling into cells (Figure 1). Then, the population of a census section, which is present in a given cell (PC1), is estimated by multiplying total population (PCS1) by the share of territorial surface falling into the cell (AC1/ACS1). The total population of the cell (TPC) is thus obtained as a sum of shares of population of all census sections, whose surfaces fall into the cell (PC1, PC2, etc.). Percentages of population aged 20-39 and 40-64 as well as that of population with higher education are calculated by dividing the relevant quantities by the total population assigned to each cell.

Finally, public subsidies are collected from the dataset of national agency disbursing agricultural funds. We use information about the payments made in the period 2008-2014 and relevant to measure 214 of the 2007-2014 RDP. In this way, we assess the influence of the 2007-2014 RDP on the concentration of organic farms existing in 2014. 2008 is the first year of effective application of the RDP (i.e. the first year when payments are made), while 2014 represents the final year of programming and corresponds with the reference year of organic farms that are present in the national register of organic operators. Data are not distinguished by sub-measure. Therefore, it is not possible to identify the amounts that are specific to organic farming. However, this should not affect results significantly, since, in the Marche region, almost the totality of the payments relevant to measure 214 are addressed to support organic farming.[7] For each payment, information about the identification code of the beneficiary is available. This code is matched with that resulting from the national register of organic operators in order to associate payments with the organic farms recorded in

[7] In the 2007-2013 programming period, 96% of total payments have been used to finance the specific action related to organic farming (Regione Marche, 2016b).

Table 1. Descriptive statistics about the data used based on a regular grid of cells with a 3-km grid size and presence of farmers (total number of observations = 1,032).

	Mean	Standard deviation	Min	Max
Organic farms (number)	2.1	3.2	0.0	46.0
Farming system				
Total farms (number)	43.5	35.5	1.0	259.0
% of arable land	57.9	32.3	0.0	100.0
UUA per farm (ha)	16.4	25.4	0.3	400.0
Labour units per ha	0.1	0.1	0.0	0.3
% of young farmers (< 40 years old)	3.0	2.8	0.0	22.0
Land use				
% of urban areas	6.2	12.6	0.0	100.0
% of natural areas	7.6	11.3	0.0	84.6
Environment				
Altimetry (meters above the sea level)	350.9	279.1	2.0	1,687.0
% of soil organic matter	3.0	1.8	0.0	10.4
Erosion (tons / ha)	12.3	5.5	0.0	26.7
Demographic and social factors				
% of 20-39 years-old population	11.3	3.2	0.0	35.3
% of 40-64 years-old population	34.6	5.9	0.0	100.0
% of population with higher education level	33.9	8.9	0.0	100.0
Policy				
2008-2014 Policy payments per ha (€)	54.3	415.6	0.0	12,513.5

Source: Authors' elaborations

the national register. In this way, the sum of all agri-environmental payments that are made to organic farms existing in each cell can be derived. Public subsidies per hectare, for every cell, are calculated by dividing the sum of agri-environmental payments by total agricultural area, obtained by using data from 2012 Corine Land Cover.

Table 1 provides some descriptive statistics about the data used. For the sake of convenience, only data referring to the cells with a 3-km size where there are farmers are shown (see methodological and results sections for an explanation).

2.4 Methods

2.4.1 The Poisson regression model

A GLM for count data, specifically a Poisson regression model, is firstly adopted. This choice depends on the objectives of the analysis and the characteristics of the dataset used. The main aim of this study is to analyse how specific characteristics of the territory affect the probability of observing organic farming in a given space. As already specified, these characteristics can be measured using data that are available at different spatial levels. Therefore, these data are converted into a common spatial reference, using regular grids composed of uniform cells. Moreover, in consideration of data availability, the distribution of organic farming can be analysed in terms of farms, represented by points that can be georeferenced within a grid, so obtaining the number of farms, i.e. a count variable, operating in each cell. In analysing count data, ordinary least squares regression cannot be adopted because count data are non-negative and discrete, tend to be highly skewed and non-normally distributed, and commonly follow a Poisson distribution (Ma *et al.*, 2012). For all these reasons, a regression model based on a Poisson distribution may be considered as appropriate.

The Poisson regression model has two fundamental components: the response distribution is not necessarily Gaussian distribution and a monotonic link function is used to transform the mean of response variables into a linear form. The probability density function of a Poisson random variable Z is given as:

$$P(Z = z) = \frac{e^{-\lambda}\lambda^{z}}{z!} \tag{1}$$

where parameter λ is the mean and the variance of random variable Z, i.e., $E(Z) = \lambda$ and $\mathrm{Var}(Z) = \lambda$. Thus, in the absence of other information, one should expect to see λ events, represented, in our case, by a given number of organic farms, in any spatial unit. Assuming that event rate λ is not constant but depends on a number of variables, which are supposed to affect the probability of observing a given number of organic farms in a given spatial unit, the Poisson regression model takes the following form:

$$\log(E(Z)) = \log(\lambda) = \mathbf{x'\beta} \tag{2}$$

where $\mathbf{x'}$ is a row vector of explanatory variables and $\boldsymbol{\beta}$ is a column vector of unknown regression coefficients. The log function is the link between the mean of the Poisson random variable and linear predictors. It ensures that the mean remains positive for all linear predictors and parameters. The Poisson regression assumes that observations are independent. However, this assumption could be invalid since the number of organic farmers, which operate in a given area, can be spatially dependent. In other words, it might also depend on the farmers located in the neighbouring space. If there is no evidence of significant spatial autocorrelation in model residuals, non-spatial methods may be appropriate. However, if statistical tests indicate significant spatial autocorrelation, methods that also consider the spatial component should be adopted (Ma *et al.*, 2012). In order to verify the existence of spatial autocorrelation, the Moran's I test (Moran, 1950) is carried out on the residuals of the Poisson regression model. Values of Moran's I range from -1 (indicating perfect dispersion) to +1 (perfect autocorrelation). The regression model is applied using different sizes of cells in order to confirm spatial autocorrelation in correspondence with different grids.[8] The choice

[8] This kind of autocorrelation could also exist between farms operating within the same cells and this would contrast with the assumption of the Poisson regression model, according to which observations should be independent. To ensure that this assumption is not violated, it would be necessary to carry out an analysis based on the use of points rather than areas. However, this would not be consistent with the objectives of this analysis and the dataset available. In fact, the aim is to assess the influence of territorial characteristics on the concentration

of distances is often an empirical issue since exact information on the size of the neighbourhood does not exist (Roe *et al.*, 2002). Following Lapple and Kelley (2015), we assume that beyond a certain distance, a spatial effect, if any, does no longer affect the adoption of organic farming. In order to allow for several neighbours per farm, 1 km is chosen as the minimum distance cut-off and Poisson models with 1, 2, 3, 4 and 5 km distance cut-off are applied. This requires the creation of grids composed of a decreasing number of cells, i.e. 9,721 (1 km), 2,525 (2 km), 1,160 (3 km), 675 (4 km), 441 (5 km).[9] The regional territory is also represented by non-agricultural areas, where zero observations are due to the absence of agriculture. This implies that the spatial autocorrelation, identified by the Moran's *I* test, could be the result of a clustering of agricultural and non-agricultural areas rather than a clustering of organic and non-organic farming. To avoid this, the Poisson regression model is applied only to those cells where there are agricultural producers, amounting to 5,785 (1 km), 2,087 (2 km), 1,032 (3 km), 622 (4 km), and 409 (5 km).

2.4.2 The quasi-Poisson hierarchical generalized linear mixed model

After confirming spatial autocorrelation, a HGLM model is then applied to analyse the influence of spatial dependence in addition to other possible factors on the distribution of organic farms. Different from linear models, HGLM models allow for inclusion, besides the usual fixed linear covariates, of an independent random location effect accounting for heterogeneity or, as in this study, a spatially autocorrelated random effect.

Specifically, a quasi-Poisson HGLM model with CAR-type specification[10] of spatial covariance (hereinafter, quasi-Poisson CAR-HGLM model) is adopted.[11] Following Lee *et al.* (2016), this model takes the following form:

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of organic farms. Data about these characteristics are not all at level of single farms (thus point data) but are, mostly, at level of space. Moreover, the reference unit of spatial analysis is given by the group of farms existing in a given cell rather than the single farm, i.e., the objective is to analyse spatial dependence between groups of farms, which can be composed of one or more units. As in Allaire *et al.* (2015), we assume that the farms located in a given space are a homogenous group, sharing, because of their location, the same territorial characteristics that influence farmers' strategies.

[9] The threshold of 2 km corresponds with the squared root of the average territorial density of regional organic farms, which is specifically one farm every 4.5 km^2.

[10] There are two auto-Poisson models that are commonly used: the SAR model (Whittle, 1964) and the conditional autoregressive model (CAR) (Besag, 1975). CAR models are very popular in spatial analysis of count data (Lee *et al.*, 2016). They are unsuitable when the spatial weight matrix is asymmetric (Dormann *et al.*, 2007) but they are appropriate in the opposite case, as happens when proximity or distance between areas is modelled. The SAR specification is a special type of CAR models, at least in a continuous-response context, and generates a less natural spatial structure (Cressie, 1995). The SAR approach is harder to apply for more complex and limited-response situations, especially when large datasets are used (Wang *et al.*, 2012,2014) and yields parameter estimates that are similar to those estimated by the CAR model (Kim and Lim, 2010). A formal and more exhaustive presentation of SAR and CAR models can be found in Wall (2004) and Glaser (2017).

[11] It should be remarked that the main interest, here, is not methodological. In other words, the aim is not to find and adopt the best model among a battery of possible alternatives but to evaluate the influence of some factors on the observed distribution of organic farms. This is conducted using one of the possible models available in literature, which can fit to the context and to the data analysed. Comparison of results associated with different models and, thus, issues related to model selection can be an interesting and future research direction.

$$f(z_i|v_i) = \phi^{-\frac{1}{2}} \exp\left(-\frac{\lambda_i}{\phi}\right) \frac{\exp\left[\left(\frac{1}{\phi}-1\right)z_i\right] z_i^{z_i}}{z_i!} \left(\frac{\lambda_i}{z_i}\right)^{\frac{z_i}{\phi}} \approx \phi^{-1} \exp\left(-\frac{\lambda_i}{\phi}\right) \frac{\left(\frac{\lambda_i}{\phi}\right)^{\frac{z_i}{\phi}}}{\left(\frac{z_i}{\phi}\right)!}$$

$$E(z_i|v_i) = \lambda_i$$

$$\mathrm{Var}(z_i|v_i) = \phi\lambda_i \qquad (3)$$

$$\log(\lambda_i) = \mathbf{x}_i'\boldsymbol{\beta} + v_i$$

$$\boldsymbol{v} \sim N(\mathbf{0}, \Sigma = \tau(\mathbf{I} - \rho\mathbf{W})^{-1})$$

where $z_i|v_i$ is the conditional distribution of the response (count) variable given the location specific random effect v_i; ϕ is a dispersion parameter; λ_i is a random intensity for location i, which equals the conditional mean, i.e. the expected value $E(z_i|v_i)$; $\phi\lambda_i$ is the variance Var $(z_i|v_i)$, where ϕ =1 gives the Poisson distribution, while $\phi < 1$ and $\phi > 1$ allow for underdispersion and overdispersion, respectively; **v** is a vector of random effects that are supposed to be normally distributed; **Σ** is the covariance matrix of the n-dimensional normal density with a CAR-type specification; **I** is an identity matrix; τ and ρ are coefficients to be estimated. In particular, ρ is known as spatial dependence parameter (Hodges, 2014), with $\rho = 0$ corresponding to independence and $\rho = 1$ corresponding to strong spatial autocorrelation. **W** is a spatial weight matrix, which defines the relationship among different locations. In other words, it defines the spatial neighbourhood for every location. There are several choices of spatial matrices, depending on the neighbouring criterion (Anselin, 2002). In this study, we use the queen contiguity, according to which two cells are neighbours if they share a common side or a vertex. Moreover, we opt for a binary approach, i.e. diagonal elements are all 0 while off-diagonal elements (i,j) are 1 if locations i and j are neighbours.[12] The grid size used is that which exhibits the highest spatial autocorrelation, since it corresponds with that for which the spatial model can be more appropriate.

The choice of this model is also conditioned on the characteristics of the sample used. In our data, there is a significant share of zero counts.[13] This situation is not infrequent in that spatial counts are often characterised by a high number of zeros (Agarwal *et al.*, 2002; Dénes *et al.*, 2015; Zuur *et al.*, 2012). The presence of more zeros than expected is a source of overdispersion, meaning that the variance is higher than the mean. Under such circumstances, a standard Poisson regression model would be inappropriate. In the literature, for modelling counts with excessive zeros, ZIP models (Lambert, 1992), hurdle models (Cragg, 1971) and their modifications have been proposed (Zuur *et al.*, 2012). These models are based on some theoretical assumptions. A ZIP model assumes that zero observations have two different origins: "sampling" and "structural". More specifically, the population is considered to consist of two types of individuals. The first type involves counts of event in a Poisson or Poisson-like process, which might also contain zeros ("sampling zeros"). The second type always gives

[12] Clayton and Berardinelli (1996) point out that a binary specification of the spatial matrix is not internally consistent in the case where the number of neighbours varies, which occurs with most irregular lattices. In this case, matrix standardization is necessary. Since the grid cells we use are mostly regular lattices, a simple specification is kept.

[13] For instance, using a grid of 3-km size, zero counts amount to about 30%.

a zero count ("structural zeros"). In contrast, a hurdle model assumes that all zero data are from one "structural" source, while the positive (i.e., non-zero) data have "sampling" origin, following either truncated Poisson or truncated negative- binomial distribution.[14] Moreover, these models apply only when there is overdispersion in the response variable. However, there are studies finding that many zeros may be associated with underdispersion (i.e. the variance is lower than the mean) for which ZIP and hurdle models would not be appropriate (i.e., Oh *et al.*, 2006; Tin, 2008). A further source of overdispersion is spatial aggregation, which leads to a higher probability of zero counts (Gabriel *et al.*, 2009). In other terms, due to spatial correlation, co-occurrence of zero counts may generate higher shares of zeros in some samples than expected under the assumption of independent observations (Lee *et al.*, 2016). In these cases, the inclusion of spatially autocorrelated random effects in regression models represents an effective way to handle the problem of overdispersion associated with zero inflation. Neglecting the issues of over- and underdispersion in analysing count data can cause several estimation problems, such as poor fit of the model, different estimates of regression parameters, and wrong inferences concerning the model parameters (Ridout and Besbeas, 2004; Tin, 2008; Ver Hoef and Boveng, 2007).

Compared with ZIP and hurdle models, the quasi-Poisson HGLM model is a more flexible solution. It does not make any specific assumption about the process that generates zeros. Moreover, it can handle both under- and overdispersion, by allowing situations where the variance differs from the mean and including random effects to capture spatial autocorrelation.[15] A quasi-Poisson regression model gives a correction term for testing the parameter estimates under the Poisson model and produces an appropriate inference if overdispersion is modest (Cox, 1983). However, in conjunction with a HGLM model, not only it improves inference but it may also produce better fits in comparison with ZIP and hurdle models, in presence of zero observations (Lee *et al.*, 2016).

Models (2) and (3) allow us to estimate the expected number of organic farms within a given space, depending on some factors. However, the probability of observing organic farms is also conditioned on the presence of farms. To take account of this aspect, a simple remedy consists in adding an exposure (or offset), in our case the logarithm of total farms, to linear predictors (Green, 2012, pp. 847-848). This is equivalent to estimate a model where the response variable is a rate rather than a count variable. This approach assumes that there is exact proportionality between the number of organic farms and total farms, since the parameter associated with the exposure is constrained to one. It is like stating that if total farms increase by 1%, also organic farms increase by 1%. However, this could be untrue since an

[14] In our study, sampling zeros correspond with farms that are organic but do not appear in the national register of organic operators. This can happen for errors, possible delays in updating the register or because farms, which are organic *de facto*, still do not undertake the procedure of certification or, also, renounce the organic certification for avoiding the relevant costs and bureaucratic obstacles. Conversely, structural zeros derive from the presence of only conventional farms. It is evident that both assumptions, i.e. there exist both sampling and structural zeros or there are only structural zeros, might be true. Therefore, the choice between ZIP and hurdle models is not neutral because, not only the initial assumption could be untrue, but the relevant estimates and interpretations could be very different (Hu *et al.*, 2011).

[15] An alternative to quasi-Poisson models, allowing for both overdispersion and underdispersion, is the so-called Conway–Maxwell–Poisson (COM-Poisson or CMP) distribution, which is a generalization of the Poisson distribution (Conway and Maxwell, 1962). One of the main differences between quasi- and COM-Poisson is that the latter requires estimation of two rather than one parameter, making the procedure of estimation more complex.

increase in total farms can be due to an increase in conventional farms. To relax this assumption, which could produce biased estimates, the parameter of the exposure is let to vary, by treating the logarithm of total farms as a further explanatory variable to be included in **x'**.

A model based on a Poisson distribution does not allow the derivation of a natural counterpart to the *R*-squared of a linear regression model, because the conditional mean function is nonlinear, and the regression is heteroscedastic. Therefore, to measure goodness of fit, several alternatives have been suggested (Green, 2012, p. 844). Here, in order to compare non-spatial and spatial Poisson-based models, we use a *R*-squared measure based on deviance residuals, which satisfies all the criteria requested (Cameron and Windmeijer, 1996).[16] Let n be the number of events, this measure takes the following form:

$$R_{DEV}^2 = \frac{\sum_{i=1}^{n}\left[\lambda_i \log\left(\frac{\hat{\lambda}_i}{\bar{\lambda}}\right) - \left(\hat{\lambda}_i - \bar{\lambda}\right)\right]}{\sum_{i=1}^{n}\left[\lambda_i \log\left(\frac{\lambda_i}{\bar{\lambda}}\right)\right]} \tag{4}$$

3. Results

Table 2 shows the Moran's *I* statistic calculated on residuals of predictions in Poisson regression models in correspondence with different grid sizes. As can be noted, the value of the statistic is always positive, indicating that the number of organic farms in a given cell increases (decreases) as the number of organic farms in the neighbouring cells increases (decreases). The relevant trend appears to be concave: it increases until 3 km, where it reaches the highest value, and then decreases. As expected, for lower values of grid size, spatial autocorrelation tends to vanish. This is because the distance between farms increases and the number of farms in each cell decreases. On the contrary, for higher values, the number of cells decreases and the concentration of farms within single cells increases with the consequence that spatial autocorrelation becomes weaker.

Results therefore confirm the presence of spatial autocorrelation, which is stronger in correspondence with a grid of 3-km size. The spatial analysis is therefore conducted using this grid size.

Figure 2 shows the distribution of organic farms over the regional territory represented by uniform cells of 3-km size. From the figure, it turns out that organic farming is a phenomenon that spreads over the entire territory. Nevertheless, it mainly localizes in the hinterland, i.e. in the medium-high hills. It is less widespread in the Eastern part of the region,

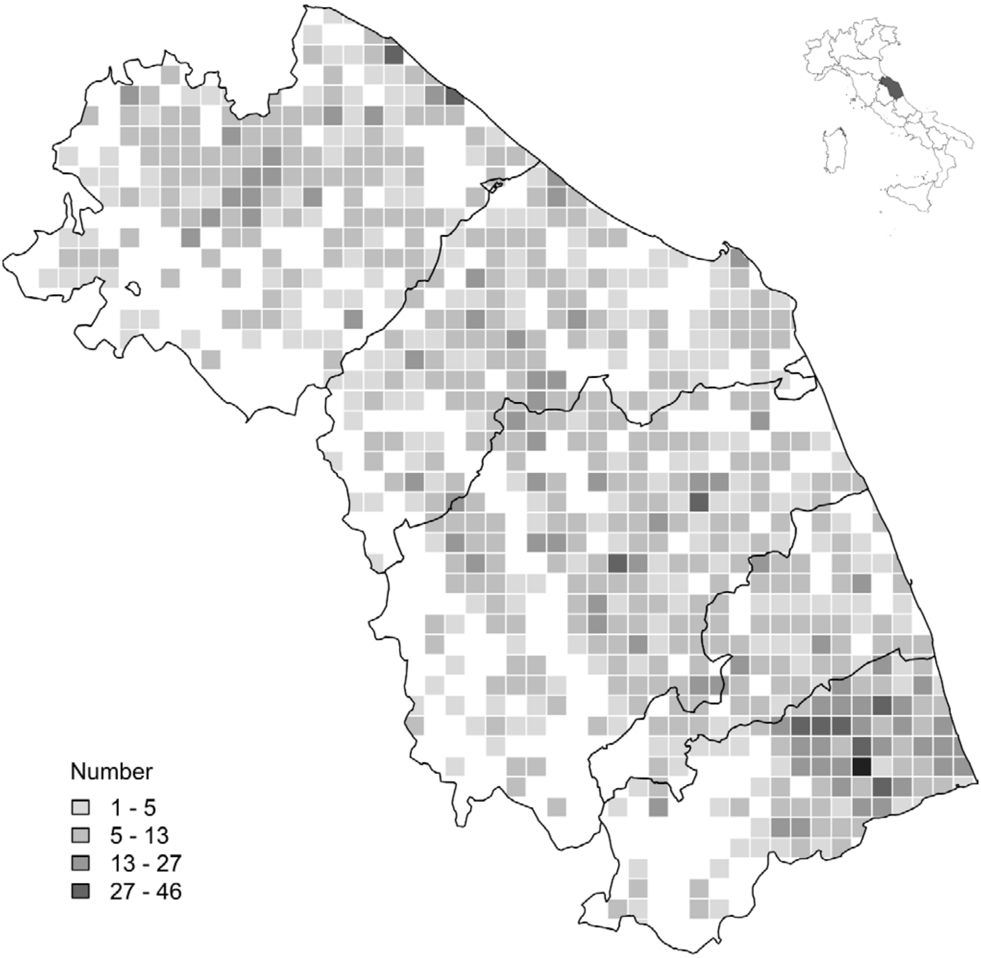
Table 2. Moran's *I* statistics for residuals of predictions in Poisson regression models for different grid sizes, Marche (Italy), 2014.

Size	Moran's *I* statistic	Variance	P-value
1 km	0.0659	0.0001	< 0.001
2 km	0.0896	0.0001	< 0.001
3 Km	0.1561	0.0003	< 0.001
4 Km	0.0954	0.0004	< 0.001
5 Km	0.0563	0.0004	< 0.001

Source: Authors' elaborations.

[16] According to Cameron and Windmeijer (1996), a *R*-squared measure should satisfy the following criteria: 1) it is included between zero and one; 2) it does not decrease as regressors are added; 3) it coincides with *R*-squared based on explained variation; 4) there is correspondence between *R*-squared and significance test on all slope parameters and between changes in *R*-squared as regressors are added and significance tests; 5) it has an interpretation in terms of information content of the data.

Figure 2. Spatial distribution of organic farms within a 3-km-size grid, Marche (Italy), 2014.



Note: administrative borders at NUTS-3 level are shown.
Source: Authors' elaborations.

characterised by flat areas. Moreover, there is a zone in the Southern part of the region and located in the Ascoli Piceno district where organic farms appear to be more concentrated. Spatial distribution of all the predictors analysed are reported in Figure A1 in the Appendix.

Table 3 shows the results relevant to application of both the non-spatial Poisson model and the quasi-Poisson CAR-HGLM model.[17] The *R*-squared based on deviance residuals are

[17] The Poisson regression model and the quasi-Poisson CAR-HGLM model are estimated by using the packages stats version 3.5.3 and hglm version 2.2.1 in R3.5.3, respectively. To solve the quasi-Poisson CAR-HGLM model, the EQL1 method available in the package is used. This method has been conceived to improve estimation for Poisson models with a large number of levels in the random effects (Lee and Lee, 2012).

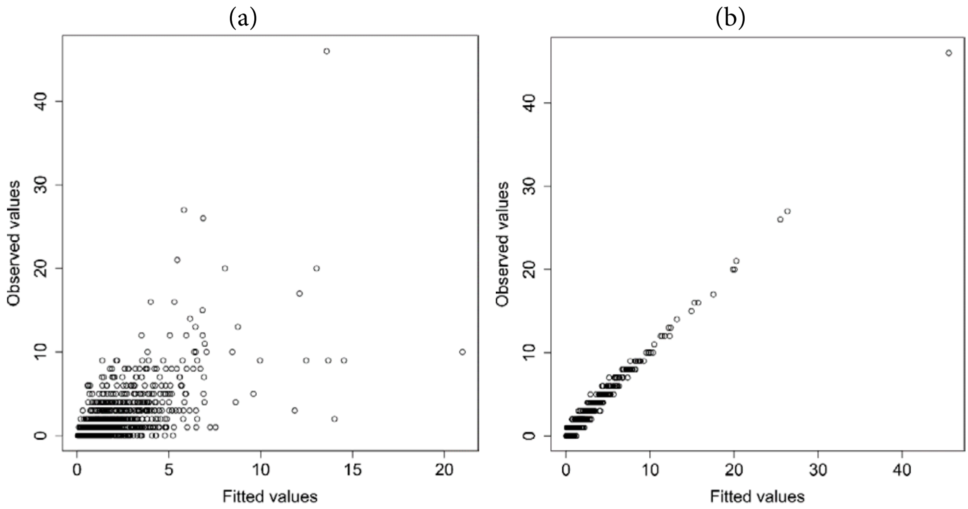
Table 3. Estimated parameters for the Poisson regression model and the quasi-Poisson CAR-HGLM model based on a 3-km-size grid, Marche (Italy).

	Poisson regression model		quasi-Poisson CAR-HGLM model	
	Coefficient	Standard Error	Coefficient	Standard Error
Intercept	-4.053**	0.547	-11.670**	1.199
Number of total farms (log)	0.584**	0.037	0.383**	0.067
% of arable land	-0.678**	0.086	-0.629**	0.214
UUA per farm	0.007**	0.001	0.006**	0.002
Labour units per ha	-2.493**	0.821	6.938**	1.978
% of young farmers (< 40 years old)	0.920 *	0.374	0.666	0.563
% of urban areas	2.734**	0.256	5.434**	0.597
% of natural areas	0.700 *	0.317	-0.491	0.611
Altimetry – meters above the sea level (log)	0.399**	0.073	0.767**	0.169
% of organic matter	-28.210**	3.684	19.360**	7.745
Erosion (tons / ha)	0.039**	0.006	0.039 *	0.013
% of 20-39 years-old population	0.051	1.185	1.941	1.905
% of 40-64 years-old population	1.488 *	0.743	0.749	1.227
% of population with higher education level	1.437**	0.360	3.193**	0.798
Policy payments (€) per ha***	0.190**	0.000	0.295**	0.000
ϕ (mean model)	1.0		0.705	
ϕ (random effects model)	-		3.262	
τ	-		0.894	
ρ	-		0.127	
Moran's I statistic	0.156**		-0.050	
AIC	3842.9		-	
R^2_{DEV}	0.415		0.904	

* p-value < 0.05; ** p-value < 0.01; *** coefficients are multiplied by 1,000 for improving reading.
Source: Authors' elaborations.

0.42 and 0.90, respectively. These values indicate a significantly higher capability of prediction of the spatial model. The different performances can also be observed in Figure 3, which shows a plot of the observed responses against the fitted values. It can be noted that the spatial model fits the observed data much better than the Poisson regression model. Looking at the parameters estimated, several differences in terms of extent, direction and significance between the two models emerge. One evident difference lies in the lack of significance related to the percentage of young farmers, the share of natural areas and the percentage of population aged 40-64 in the spatial model. These coefficients are instead significant and markedly higher (in absolute terms) in the non-spatial model. Further deviations are the extent and the direction of significant coefficients in the spatial model. The relevant coefficients are clearly

Figure 3. Plots of observed and fitted values for (a) Poisson regression model and (b) quasi-Poisson CAR-HGLM model based on a 3-km-size grid, Marche (Italy).



Source: Authors' elaborations.

higher (in absolute terms) in the cases of labour units per hectare, proportion of urban areas, altimetry, share of population with higher education and public subsidies, while they are lower especially with reference to the number of total farms and the percentage of organic matter. Labour units per hectare and the percentage of organic matter have also opposed sign. These results stress the importance of using spatial models if spatial autocorrelation is detected.

Focusing on the spatial model, coefficient ρ indicates the presence of some spatial dependence consistently with the results related to residuals of predictions in the non-spatial regression model. The Moran's I statistics is around zero and the hypothesis that its value is significantly different from zero can be rejected, indicating that there is no more spatial autocorrelation in residuals.

Dispersion parameter ϕ regarding the mean model is lower than one, indicating the presence of underdispersion, while the one related to random effects, which captures spatial autocorrelation, is higher than one, suggesting, in this case, overdispersion. The joint presence of under- and overdispersion legitimates the use of models that can take into account both phenomena.

Analysing the estimated parameters, the results related to farming system firstly show that organic farms are present where there are also other farms. This is an obvious result. However, it is interesting to note that there is not a direct relationship. The relevant coefficient indicates that if total farms increase by 1%, organic farms increase by 0.4%. This means that the distribution of organic farms and that of conventional farms do not follow the same pattern. The coefficient related to the share of arable land shows a negative and significant relationship between productive specialization in arable crops and numerosity of organic farms. The parameters associated with the average farm size and labour intensity are also significant but with opposite signs.

Looking at land use, the number of organic farms is positively and significantly related to the percentage of urban area. In relation to environmental characteristics, positive and significant coefficients are also found in the cases of altimetry, share of organic matter and levels of erosion.

With regard to socio-demographic factors, there is a positive and significant relationship between the share of population with higher education and the presence of organic farms. Finally, the coefficient associated with the incidence of public subsidies is positive and significant. Its value measures the logarithmic difference of expected organic farms due to an increase of one unit in public subsidies per hectare, keeping the other predictor variables constant. It suggests that, to increase organic farms of one unit, it would be necessary to increase total public payments of about 3,400 €/ha, corresponding to an annual payment of 485 €/ha. This value can be interpreted as an average measure of the willingness of regional farmers to convert towards organic farming and could be used as a reference parameter to define premiums in favour of organic farming.

4. Discussion

Results show that the distribution of organic farming is spatially clustered, confirming previous studies. From mapping, it turns out that organic farming tends to concentrate particularly in the hinterland. The concentration of organic farms in the Southern part of the region coincides with a specific cluster of organic operators, the so-called "Bio-distretto Piceno"[18], born in 2014 and promoted by AIAB, an Italian association of organic farms. The econometric model confirms that there are spatial spillovers across territorial units. In other terms, the presence of organic farms in one territorial unit both affects and is affected by the presence of organic farms in the neighbouring units.

Results also indicate that the distribution of organic farming, in addition to neighbouring effects, relates to a number of territorial and political factors. In particular, in line with previous studies (Häring *et al.*, 2004; Koesling *et al.*, 2008), the concentration of organic farming is stronger where there are higher levels of urbanization. This can depend on the adoption of marketing strategies requiring a closer and stricter relationship with consumers, mainly localized in urban areas. Education is a further socio-demographic factor that relates to the distribution of organic farming. Organic farms are more numerous where there is a higher share of more educated people. The reason for this could be a greater propensity of people with higher levels of education to purchase organic products (Zepeda and Li, 2007; Wier *et al.*, 2008).

With reference to farming system, results also show that organic farms are generally located in territories that are not specialized in arable crops and where there is a more intensive use of labour. Moreover, in the areas where there is a higher concentration of organic farms, existing farms have generally a higher average size, confirming that a larger size offers more chances to apply extensive technologies that are typical of organic farming (Pietola and Lan-

[18] A "Bio-distretto" is defined as a geographical, functional and non-administrative area where a partnership between farmers, citizens, tourist operators, associations and public administration is established for ensuring sustainable management of resources. This synergy occurs on the basis of principles and activities of organic production and consumption (short supply chains, organized groups of consumers and producers, high-quality restaurants, public canteens) (Basile, 2014).

sink, 2001). As regards environmental characteristics, there is a higher diffusion of organic farming in less flat areas. Organic farms are also more present where there are higher levels of erosion but also a higher content of organic matter in soils, in contrast with previous studies (Lewis *et al.*, 2011; Gabriel *et al.*, 2009; Wollni and Andersson, 2014). These findings can be read together. In fact, in medium-high hills, characterized by stepper slopes, problems of soil degradation due to surface water flows are graver. However, these areas are also less involved by intensive agriculture and are therefore richer in terms of organic matter. Therefore, we can conclude that organic farms localize far from more competitive agriculture, characterised by a high specialization in arable crops and a more intensive use of mechanisation and chemicals. A reason for this could be lower costs of conversions to organic farming for farmers adopting agricultural methods that are already based on low levels of chemicals and mechanization (Häring *et al.*, 2004). Another explanation can be the level of public payments per hectare, which can be too low for more competitive farms to render organic farming profitable, if compared with their relatively higher economic returns (Pietola and Lansink, 2001). Therefore, organic farming seems to represent an economic alternative for that part of farms located in areas that are morphologically less suited to intensification.

From a policy point of view, results show that there are more organic farms where payments per hectare of total agricultural area are higher. This contributes to confirming the importance of policy support in promoting organic farming. In the light of the other results, it appears that policy support mainly provides incentives in more remote areas, subject to erosion and more fertile. This can be positive for maintaining agriculture where the risk of abandonment is higher, also ensuring environmental protection from phenomena of erosion. However, there might be some inconsistency between the objectives of favouring organic farming and those of increasing environmental sustainability. If it is true that organic farming can help to reduce the environmental pressure generated by farming, it could be strategic to favour diffusion of organic farming also in areas where this pressure is higher, i.e. areas specialized in arable farming where there is a higher level of soil exploitation, and a higher use of fertilizers, chemicals and mechanization. Support to organic farming, especially if it represents most agri-environmental payments, as is in the region under study, should also be targeted in relation to environmental characteristics (European Court of Auditors, 2011). This is because differentiating support spatially on the basis of given environmental issues can increase cost-effectiveness of agri-environmental measures (Uthes *et al.*, 2010; van der Horst, 2007). Analysing the system of incentives in favour of organic farms, it turns out that, during the 2007-2014 programming period, the maximum annual payment per hectare was on average 372 €/ha for introducing organic farming and 320 €/ha for maintenance (Regione Marche, 2015b). These values are lower than the average threshold estimated by the model to favour the appearance of an additional organic farms and are about 40-50% lower than the average threshold established by the Regulation (EC) No 1698/2005 (650 €/ha). The system of compensation differentiated between crops and between areas, ensuring higher premiums for farms located in areas other than the mountains, but only with reference to maintenance. In other words, a single premium for introducing organic farms, distinguished by type of crop, was assigned to farms independently of their localization. As for maintenance, the difference between the premiums granted to the farms located in areas other the mountains and those received by mountain farms was 40€/ha, i.e. just 13% higher. In addition, the regional system awarded with similar scores applications from farmers located in nitrate vulnerable zones and in Natura 2000 sites, as well as livestock farmers raising cattle with organic methods. Therefore, several critical elements emerge, i.e. a relatively low level of premiums, the lack of territorial differentiation with regard to the premium for introducing organic farming, the small difference in terms of premiums for maintenance between areas, and the scoring system, which equates farmers operating in environmentally critical areas, those located in protected areas and livestock farmers that are already organic. Granting a higher support, in consideration of available margins, and awarding, to a higher extent, conventional farmers located in environmentally critical areas in both phases of application (introduction and maintenance) could have produced better results in terms of achievement of environmental objectives. Looking at the 2014-2020 RDP of the Marche Region, it turns out that, consistently with our suggestions, premium levels were increased by about 20% and the scoring system was revised by giving higher priority to conventional farmers with intensive production, who decide to convert to organic farming (Regione Marche, 2017a,b). However, territorial differentiation of premiums was completely abolished and only a single premium, though distinguished by type of crop, was introduced. Moreover, with reference to the maintenance of organic farming, in selecting applications, a lower priority was attributed to farmers with intensive production, giving more importance to those located in Natura 2000 sites, where constraints are surely more stringent, but the environmental benefits of organic farming are also lower. Therefore, although a few improvements have been made in comparison with the previous programming period, some policy choices are still questionable and should be rediscussed to better target policy support in relation to environmental issues.

In interpreting results, some caution should be taken owing to a few possible limitations. Besides potentially different results that can derive from applying alternative models (such as ZIP, hurdle, negative binomial or COM-Poisson models), a possible drawback is that the regression analysis applied might suffer from endogeneity. Technically, this problem occurs when a predictor variable in the model is correlated with the error term. This can happen for a variety of reasons (Fingleton and Le Gallo, 2008). However, the most relevant one in this study is the possibility that the outcome variable is also a predictor and not only a response (the so-called "simultaneity bias"). Firstly, simultaneity bias may concern factors related to the prevailing farming system, since the characteristics of existing farms may reflect those of organic farms, especially in the cases where organic farms represent the majority. However, considering that organic farms only represent 5% of total farms and that the percentage of organic farms is higher than half only in less than 2% of cells where there are agricultural producers, the influence of organic farming on the existing farming system, if present, appears to be rather limited. Endogeneity issues can also concern environmental factors such as the levels of erosion and the content of organic matter. This is because the presence of organic farms could help to reduce soil erosion and to increase or, at least, to maintain the percentage of organic matter contained in soils. However, the results related to soil erosion indicate the contrary, i.e. organic farms tend to localize where the levels of erosion are higher. Moreover, observing the territorial distribution of soil organic matter (Figure A1-i), the content of organic matter increases as we move towards the hinterland. This highlights a natural phenomenon due to the morphological characteristics of the region, which is possibly affected by the distribution of all agricultural activities, rather than a result of organic farming. Endogeneity can also be concerned with the variable related to policy. In fact, a higher concentration of organic farms could be the reason for a higher incidence of policy support per hectare. In this case, it is like stating that organic farms are not incentivized by policy, but they recur to policy support only because there exists this financing opportunity. In other words, a farm becomes organic also without policy. This would be an even stronger conclusion which does not take into account the selective criteria and the obstacles that exist when applying for receiving policy support. Nonetheless, although the possibility of some endogeneity still remains, the main objective of this study is to investigate contextual factors that are more favourable to the concentration of organic farming rather than analysing causal relationships at level of single farm, for which the issues related to endogeneity can be more relevant.

5. Concluding remarks

This study has analysed the spatial distribution of organic farms in the Marche, an Italian rural region. This region is an interesting case because, in consideration of its peculiar environmental characteristics, organic farming could give an important contribution to mitigating or avoiding current and potential environmental impacts that agriculture generates. In particular, this analysis has assessed whether and the extent to which the distribution of organic farms is related to some economic, social, environmental and political factors. To this aim, a quasi-Poisson CAR-HGLM model has been adopted. This model provides high flexibility since it does not make any assumption about the distribution of zeros, allows for both under- and overdispersion, and takes account of spatial dependence in measuring the influence of some possible explanatory factors.

Results indicate that there is a tendency to spatial concentration, i.e. organic farming develops where there already exist other organic farms. Besides neighbouring effects, there are other factors affecting the spatial distribution of organic farming. Indeed, results show that organic farms concentrate where there are more favourable market conditions, i.e. an easier access to consumers and a higher propensity to purchase organic products. In addition, organic farms tend to localize far from the areas where there is a more intensive use of mechanization and chemicals, and where they could give an important contribution to attenuating environmental pressure. Factors such as different conversion costs and low incentives could have acted on this spatial distribution. From a policy perspective, organic farms reveal to be sensitive to public intervention. Policy appears to be effective in stimulating organic farming where there are more problems of erosion, but it seems to be ineffective where the environmental pressure exerted by intensive farming is higher. This is attributed to an inadequate territorial differentiation of support and to the scoring system for selecting applications, in addition to low levels of premiums. For ensuring more consistency with environmental objectives, it is suggested that payments in favour of organic farming should be increased and that the management system must be revised, by territorially differentiating incentives to a larger extent and by giving more priority to farmers with intensive production.

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Short Communication

Competitiveness of cattle breeding in Switzerland: the value of policies enabling informed decisions

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Abstract. Using the case of of Swiss Brown Cattle breeding, this paper develops the hypothesis that a two-angle strategy of fostering competition and providing maximum access to information is promising for states to attain high competitiveness on a national level. Abandoning the monopoly on bull sperm while subsidising classifications of animals in order to provide a maximum base of knowledge helped to increase Switzerland's self-sufficiency in Brown Cattle sperm from under 50 to almost 100 per cent.

Keywords. Switzerland, cattle, breeding, information economics.

JEL Code. Q13.

1. Introduction

The debate about appropriate policies for attaining competitiveness by sectors and nations has long been centred around traditional lines between hands-off liberalists and interventionists. The aspect of how governments should deal with information management is gaining importance in this respect. In Section 2, the literature of the role of the state in handling information is reviewed and arguments about why and how governments should facilitate sufficient access to information to increase sector competitiveness are provided.

Cattle breeding in Switzerland is a sector in which information plays a crucial role in becoming competitive and therefore is a well suited case study to illustrate the effect of information policy on competitiveness. In the Swiss Brown Cattle market in Switzerland, domestic sperm has increased its market share considerably over the last decades from under 50 to almost 100 per cent. Changes in the political regime were an important driver in this process. On the one hand, the government abandoned the monopoly on bull sperm, on the other it provided incentives to generate and use genetic information . In Section 3, the effect of this policy is described. Section 4 focuses on the limitations of this case and offers some conclusions.

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2. Theoretical Framework

While information has been defined in general as a reduction of uncertainty (Sivak, 1996), its use in economic science is ambiguous. On the one hand, institutional economists have shown that the functioning of all markets is strongly dependent on the scale and scope of available information On the other hand, information is a tradable good, and market research companies, consultancies, publishers and many other enterprises owe one of their main justifications to the existence of the market for information.

The latter perspective is needed when exploring reasons why the state might want to interfere in the market for information. One of them is distributional justice (Craig *et al.*, 2008). This is a factor that mostly justifies state intervention in the case of information asymmetries (Mann and Wüstemann, 2010; Mann, 2017). Beyond that, however, the character of information as a public good or as a merit good must be reviewed in some depth in order to arrive at tangible conclusions with regard to the rationale for state intervention.

2.1 The public good aspect of information

When Samuelson (1954) determined nonexcludability and nonrivalry as criteria for public goods, no one expected his brief text to reshape the way economists thought about the distinction between private and public goods (Nordhaus, 2005). Samuelson himself was rather clear that information qualified as a public good (Samuelson, 1958), mainly with respect to media, such as radio and television, where the dissemination of information would nether be excludable nor create problems like rivalry.

Subsequent scholars have shown that the actual state of affairs is more complex. Bates (1990), for example, demonstrated circumstances in which information has private good properties, and others in which it does not. At the same time, Allen (1990) emphasised circumstances under which information generates a price, thereby qualifying it as a private good. Complicating matters further, Antle (1999) suggested that information, though noncompetitive, is excludable, such that it would qualify as a club good.

The least that can be concluded from this debate is that information can be treated in extremely different ways. Suppliers of information, like advertisers, may attempt to spread information as widely as possible. In other cases, both in business and private affairs, information may be sealed and never disclosed, or it may be carefully sold to a single person. Similar choices are made on the demand side. Some buyers of information are eager to share it (such as educational bodies), whereas others seek to conceal it.

Public entities create increasing pressure to make information public. Lewis (2012) argued that Gold Open Access, which grants access to all articles at all times, is a disruptive innovation, but one which is likely to cover a major share of the journal market. Governmental bodies, including the European Commission, have pushed for the accessibility of research results, not only technically in terms of open access, but also in terms of transfers of knowledge through the use of simple language and popular media (Olff, 2014). It is indeed plausible that spreading information, or at least making it available on demand, increases its potential benefits much more than its potential costs.

This leads to an often neglected opposition of interests: Limiting access is strongly in the interest of those who want to gain benefits from either selling information or concealing it

(Nisbet and Lewenstein, 2002), whereas the public has an interest in making information as widely accessible as possible. The conflict around patent law, with its struggle to find a 'balance between commercial profitability and public-interest concerns' (Maskus and Reichman, 2004, 283) is an exemplary illustration of this unavoidable clash of interests.

2.2 The merit good aspect of information

When Musgrave (1957, 1959) suggested that the state, in some cases, should impose the consumption of certain goods in spite of the absence of demand among consumers, the concept attracted little support from mainstream economists. Forty years later, Thaler and Sunstein (2008), based on their expertise in behavioural economics, introduced the concept of libertarian paternalism. It has been shown (Mann and Gairing, 2012) how strongly related their preference for 'nudging' people into making rational choices was to the 'merit good' concept. The Nobel Prize awarded to Richard Thaler in 2017 confirms how clear it is today that our decisions are occasionally irrational, and that it would benefit us if the state was more involved in our decision making.

One classical example of such a case is our demand for education. Even before Musgrave (1957, 341) first mused about 'the apparent willingness of the public to provide for a second car and a third icebox prior to ensuring adequate education for their children', it has become common for the public to finance the bulk of primary, and often secondary, education. Poutvaara (2008) even named a number of countries that finance 100 per cent of tertiary education. It would be technically possible to trade education on the free market; parents would buy kindergarten and school programmes as they would food and clothing. As such, there is little trust among policy makers that this would lead to the sufficient education of children, and probably rightly so.

The necessary process of consuming food generates pleasure, which is probably the reason why paying for food is condoned. As we all know, however, obtaining new knowledge and learning about methodologies do not always generate the same feelings of satisfaction and pleasure. This is likely the reason why the state not only pays for but also encourages or even forces us to receive an education. Only from around the age of 20-30, when we have sufficient knowledge to participate in the labour market, do states leave the decision to continue education to market forces.

2.3 Institutional options for intervening

Leaving the availability of information solely to market forces is neither recommended by economists nor considered a good practice in many countries. This leads to the question of how to institutionalise interventions into markets for information.

When discussing the failure of real-world socialism, most political economists (e.g., Elson, 1988; Prybyla, 1991; Li, 2013) agree that both an incentive and an information problem were the main causes for the failure of the system. The information problem's underlying mechanism was that competition generates information (Tang, 2018). Both the success and failure of actors on the market, as indicated by overdemand and lack of demand, are important signals for the preference functions of consumers in a given region, country or even worldwide.

The incentive and information problems are interlinked: When facing increased competition, the incentive to collect sound information on consumer preferences rises, i.e., part of the more intense information flows is fostered by incentives for successful performance on the market.

However, the main advantage of competition in terms of information is that outsiders have a fair chance. In administered markets, the 'usual suspects' are often in charge, whereas it has often been shown (Timmons, 1994; Faltin, 1999; Henoch, 2006) how entrepreneurship introduces new approaches and ideas to tackle problems. Translating this phenomenon into information economics, outsiders may sometimes have better ways of covering demands than actors from within the system, which is important information that should be spread.

2.4 An approach for enabling informed decision making

The complex functions and characteristics of information in contemporary markets reject simple solutions with respect to the classic dichotomy between interventionists and non-interventionists. Scholars who are in general supportive of governmental interventions into markets will find it difficult to accept that all limitations set on competition should be avoided. Any attempts by governments to steer markets in special directions by excluding either players or options are counterproductive, as they decrease the amount of accessible information.

Government interventions, however, are highly appropriate when it comes to the accessibility of information. There is a tendency among information providers to disclose their findings to the non-paying public, and there is also a tendency among information consumers to underinvest in this crucial commodity. This creates likely gains if governments take care to provide data which the public can access at a low cost.

Combining these two elements leads to a strategy for maximising the accessibility of information that will become increasingly important in the Information Age.

3. Empirical methodology

Information is not equally important in each sector. For competitiveness, for example, in the energy or transport sector, infrastructure will be more important than the availability of information (Kljajic *et al.*, 2016; Dolinavova *et al.*, 2017). In other sectors like finance, trust is probably the most important resource (Namahoot and Lavichien, 2015). It is therefore useful to focus on a sector where the role of information is rather above average.

This applies to the market for genetic material in agriculture. Breeding activities require a vast amount of information to be successful. Habier *et al.* (2007), for example, emphasised the importance of genetic relationship information for the breeding values of Holstein cattle. Iezoni *et al.* (2010) illustrated the advantages of an integrated framework of marker-assisted breeding in Rosaceae fruits. Yates *et al.* (2018) demonstrated the need for professional data management for successful crop breeding programmes. The targeted selection of valuable attributes of a species requires much information about the available material.

This also applies to cattle breeding where the largest database internationally, being situated in the United States, has been documented to markedly improve the quality of breeding

(Weigel *et al.*, 2017). While smaller nations attempt to catch up (Lidauer *et al.*, 2006; Fürst *et al.*, 2011), it seems questionable if smaller nation with their lower level of centralization are capable of staying competitive.

Switzerland appears as an ideal test case, as Swiss actors had at one time lost any market power over breeds originating from Switzerland, but regained this power through a series of political adaptations. This development may therefore serve as a case in point to test the theoretical points made above. Both a thorough analysis of the agricultural press in the time between 1996 and the present and in-depth talk with core actors and trade data were used. This included the use of descriptive statistics, but also of content analysis of recorded and transcribed interviews.

The case of Swiss Brown Cattle is also economically relevant as it still constitutes the majority of all dairy cows in Switzerland. This economic dimension, the high dependency on information in animal breeding and the strong dynamics in the breeding of Swiss Brown Cattle make the case worthwhile to find out more about the role of governments in information management of a sector.

4. The case of breeding swiss brown cattle

4.1 Trade development

As in large parts of the contemporary developing world (Vasconcelos Dantas *et al.*, 2018), in Switzerland until the 1970s, local bulls were in charge of inseminating most cows. Then, artificial insemination was introduced, which allowed the selection of the genetic material with the best performance on an international scale. Figure 1 indicates that the option of sperm imports was readily taken up around the turn of the century, even for Brown Cattle, for which the genetic centre is situated in Switzerland, where there are around 200,000 Brown Cattle animals, more than in any other country. While import values of the sperm of Brown Cattle have peaked at around 10 million USD per year, the degrees of self-sufficiency in sperm for other breeds were even lower at that time.

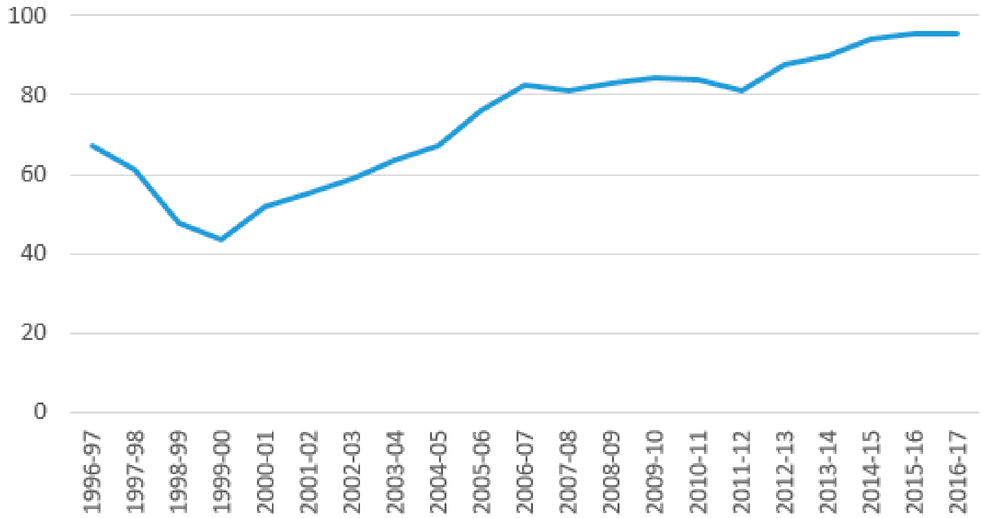
Figure 1 shows the market dynamics of the last 20 years. While the degree of self-sufficiency approached values close to 100 per cent, export figures also rose, mostly to adjacent countries like Austria, Germany and Italy. With such a development, sperm is a clear exception to the rule of Switzerland's generally very low competitiveness in the farming sector (Mann *et al.*, 2011) and agricultural factor markets, in which the country is a net importer of almost everything from machinery to feed to fertilizer.

Switzerland's currently strong position not only translates into market figures. At the last European Brown Cattle contest, Swiss animals won all champion titles as well as the national cup. Italy and France took second and third positions, respectively.

4.2 National monopoly and American expansion

In order to steer the development of this technological innovation, the Swiss Association for Artificial Insemination was founded in 1961 and received a monopoly on both producing and selling semen boxes. The European Green Press in the fourth quarter of the 20^{th} century in general highly favoured the international collection of good bull semen (e.g., Diers, 1990).

Figure 1. Degree of self-sufficiency of Brown Cattle sperm in Switzerland.



The main beneficiaries were American breeders. Heimig (1995) mentioned four American companies entering the German market for cattle breeding at the same time.

Breeding objectives were an important factor leading to this development. Over many decades, Swiss breeders emphasised the small sizes of cows and prioritised several aesthetic factors, whereas American breeders tended to focus on milk yields. Welter (1998) portrayed a Swiss breeder who travelled to the US on a yearly base to collect promising genetic material, strongly criticising Swiss breeding strategists.

The only export of Swiss Brown Cattle at that time was heavily subsidised. By paying 1000 Swiss Francs for every bull being exported, the government fostered an annual export of 10,000 live animals per year, an uncompetitive and particularly animal harming way of distributing genetic material. These subsidies ceased in 2010, causing an immediate end to this trade flow.

4.3 Liberalisation and information policy

The decade between 1995 and 2005 was a period of transformation for the Swiss farming sector. Market support in general was strongly reduced, and farmers received direct payments as compensation. In parallel, the state's strong grip on genetics was also loosened. In 1995, the monopoly of the Swiss Association for Artificial Insemination was removed so that other organisations could start to apply for a license. In subsequent years, cantonal administrations transferred their shares of the Association towards breeding associations, while the insemination organisation itself was transformed into a commercial company in 2004. Finally, the requirement of a license to enter the trade of sperm was removed in 2005. Today, two Swiss companies select bulls for genetic purposes and sell their sperm, while two additional competitors specialise in the retail sector.

Letting market forces work, however, was not the only strategy of the administration. While the Swiss government traditionally offers a large range of subsidies to support farmers, the following support payments, adding up to 23 million Swiss Francs per year, fall into the range of cattle breeding:

- Two-thirds of the money is used to regularly measure the milk yields of dairy cows and to feed them into a broadly accessible database. This enables breeders to distinguish promising from average bulls
- The database in which not only milk yields but also other characteristics and genetic linkages are stored is called herdbook. The majority of costs for managing the herdbook are also covered by the federal administration.
- Minor budgets are available for collecting and storing information about outer appearance, meat quality and health status, all of which deliver supplementary information about genetic qualities.

This way, the accessibility of information for farmers has been smoothened. They do not only receive data from the herdbook and similar sources for free, they are also encouraged financially to feed in the information of their own animals. As a result with a high accessibility of information, this contributes for dairy farms to finding the most promising bull (i.e. genetic information) for their herd.

5. Discussion and Conclusions

It appears that the framework as developed in Section 2 is fully confirmed by the case of Brown Cattle breeding as depicted in Section 3. Table 1 summarizes the two aspects of the strategy that should foster competitiveness in information-intensive sectors and illustrates it with the case of cattle breeding.

It is plausible that the unprecedented success in regaining market shares of Brown Cattle breeding in Switzerland has been caused by a combination of liberalisation and intervention. Innovation often comes from unexpected directions, and competition gives a voice to such unlikely candidates. However, subsidising the structured management and accessibility of all relevant information has been the necessary second step to make use of the information generated in the field.

However, while allowing for competition and providing full access to the relevant information will in general be a promising strategy, it would be premature to declare it a panacea for competitiveness. Not all markets are as fully dependent on information as the market for

Table 1. A framework for strengthening competitiveness in information-intensive sectors.

	General strategy	Realisation for cattle breeding
Information generation	Let as much information as possible be generated in a decentralized way	Enable breeding efforts bottom up
Information dissemination	Make information as accessible as possible	Subsidize integration of animal information in database

genetic material. Other well-known factors for competitiveness, such as natural conditions or access to capital, remain important, probably more so for many markets.

For future research, it will therefore be crucial to identify sectors and branches with a similarly high reliance on information as the breeding market. For such cases, it should be possible to test whether the combination of competition and supportive access to information proves to be equally helpful to national competitiveness.

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