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Foreword

After being the Guest Editor of the 120-2 issue, this is my first issue as Editor-in-Chief of Studies in Agricultural Economics. As a common practice, I would first like to give my vision and ideas for the future of the journal. I think Studies in Agricultural Economics has its place in the international market and is generally recognised but more is needed. I believe that all stakeholders around the journal should work on increasing the Journal's scientific value and thereby its recognition in order to receive a Scopus Q value and a Thompson Reuters impact factor. In order to achieve this ambitious goal, some changes are necessary, as follows.

First of all, I believe the focus of the Journal should be realigned. Studies in Agricultural Economics currently positions itself as a Central and Eastern European journal publishing original papers in various fields related to agricultural economics and rural development. As there are many other journals in this region with the same 'strategy', the Journal should change its focus. In doing so, I would change the geographical coverage by stating that Studies in Agricultural Economics is a journal for Europe and Central Asia, which is more in line with international standards and would result in more papers and better citation statistics.

Second, I think the current website of the Journal has well passed its sell-by-date. A new website is needed, based on international standards, which is independent from the website of the Research Institute of Agricultural Economics. Moreover, the Hungarian and English sites should be treated independently, unlike current practice.

Third, a reorganisation of the Editorial Board is also necessary. The current Editorial Board consists of 29 members, out of which 12 are Hungarian. I think some Editorial Board members are not very active and some of them also lack an international reputation. I would change the structure of the Board by trying to retain those who are committed and invite some new colleagues in line with the Journal's broadened economic focus. I think a new policy is needed so that Editorial Board members know what their role is and what the Journal expects them to do. The new Board should also have a balanced geographical distribution.

Last but not least, audience attraction is also a key area where changes are needed. On the one hand, the lack of a high number of well-written papers is detrimental to the Journal's quality, so it should be guaranteed that there are always good papers to select from. This positive pressure might be elevated by organising a special (thematic) issue each year, resulting in a number of beneficial effects (e.g. more papers, better citation records, more scientific debate). On the other hand, readership should also be increased by publishing more papers on 'hot topics'.

I believe this issue well fits into the 'revised strategy' of the journal outlined above by selecting papers and topics from all around the world that has a certain relevance to our readership. The first paper, written by Ciaian, Rajcaniova, Guri, Zhllima and Shahu, analyses the impact of crop rotation and land fragmentation on farm productivity in Albania. By employing a stochastic production frontier estimation approach to an own survey dataset, their results suggest that land fragmentation and crop rotation improves farm efficiency.

The second paper, written by Wongprawmas, Canavari, Imami, Gjonbalaj and Gjokaj, also concentrates on the region – the authors investigate attitudes and preferences of Kosovar consumers towards quality and origin of meat. By analysing a sample of 300 Kosovar consumers, results suggest that Kosovar consumers perceive domestic origin as an indicator of meat quality and safety. Moreover, the conservative and innovative food consumer profiles with different consumption habits were identified in the paper, offering important implications for decision makers along the meat supply chain.

The third paper in this issue, written by Török and Moir, provides a review of the empirical literature on the market size of food with Geographical Indications (GIs). Their results show that there are only very limited data available on the actual market size for GI labelled products. The authors find a high level of concentration of GI products in terms of origin and product category. The also find that GI products with both significant market size and remarkable market share also exist, but these are a small set of all registered GI products and are concentrated in only a few countries.

The fourth paper, written by Leitao, also talks about a European story but from a different perspective. The author investigated the relationship between carbon dioxide emissions and Portuguese agricultural productivity by using a time series for the period 1960-2015 and found that agricultural labour and land productivity as well as agricultural raw material exports were positively related to CO2 emissions, thereby stimulating environmental pollution.

The fifth paper, written by Djokoto and Pomeyie, also takes and environmental approach and analyses the productivity of organic and conventional agriculture by using a common technology analysis for 74 countries over 2005 and 2014. They found conventional agriculture to be more productive than organic agriculture. According to their results, for every hectare of conventional agricultural land given up, only 0.54 hectares of organic land area is substituted.

The remaining two papers suggest evidence from Peru and Korea with important implications to Europe. The paper written by Urriola Canchari, Aquino Rodriguez and Baral quantify the short- and long-run impact of agricultural exports on the economic growth of Peru using nnual time series data from 2000 to 2016. Their results suggest that traditional agricultural exports have had a positive but non-significant effect on economic growth, while non-traditional agricultural exports have had a positive and significant effect on Gross Domestic Product (GDP). Moreover, both fixed capital formation and the labour were found to have a significant effect on the GDP, albeit in different directions.

Last but not least, Kim and Tejeda analysed the implicit cost of the 2010 foot-and-mouth disease in Korea by using a seasonal autoregressive model to Korean swine slaughtering data. Results show that the unaccounted implicit cost is estimated to be more than 2 trillion Korean Won (≈ 1.8 billion US dollars), which is a cost Korea must give up or cannot recover. The authors justifies the need for a country to apply preventive efforts to reduce the likelihood and economic impact of an animal disease outbreak.

On the whole, I think this issue well fits into the plans for Studies in Agricultural Economics to increase its scientific impact and reputation. I hope that my vision and ideas will become reality in the near future.

Jámbor Attila
Budapest, December 2018

Pavel CIAIAN*, Miroslava RAJCANIOVA,***, Fatmir GURI****, Edvin ZHLLIMA**** and Edmira SHAHU****

The impact of crop rotation and land fragmentation on farm productivity in Albania[1]

In this study, we estimate the impact of land fragmentation and crop rotation on farm productivity in rural Albania. We employ a stochastic production frontier estimation approach to survey data collected among farm households in Albania in 2013. Our estimates suggest that land fragmentation improves farm efficiency, probably because it permits a better use of household labour during the production seasons. Our estimates also suggest that crop rotation increases farm efficiency. However, the impact of land fragmentation on on farm efficiency is far more pronounced.

Keywords: land fragmentation, crop rotation, stochastic production frontier, farm efficiency

JEL classifications: Q12, Q15

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Introduction

Agriculture remains one of the most important sectors in the Albanian economy, representing one fifth of the country's GDP and around half of total employment (INSTAT, 2016). During the early transition period in 1991, Albania adopted a land reform which led to a radical structural change. Before 1990, 622 collective and state farms used all agricultural land in Albania with an average size of 1065 hectares per farm. The average plot size was 38 hectares. The 1991 land reform led to dismantling of the collective and state farms which had a significant impact on the current state of the farming sector and land use. The reform caused an extensive land fragmentation characterised by numerous and scattered plots per farm, primarily because land was divided equally per capita and by land type within each village. Overall, there were created around 350 thousand small family farms (with an average size of 1.2 ha) cultivating 1.9 million small plots (an average of 4.9 plots per farm) with each plot having an average size between 0.25 and 0.3 hectares (Zhllima and Guri, 2013), often badly shaped and located far from each other and from farm houses (with distances ranging from 1 to 10 km) (Civici, 2010) (Table 1).

Table 1: Structural changes to agricultural land.

	Unit	1990	1994	2012
Number of farms	No.	622	445,000	350,000
Average farm size	ha	1,065	1.2	1.2
Average plot size	No.	38	0.2-0.3	0.26
Average number of parcels per farm	No		3.3	4.9
Total number of parcels	million		1.9	1.7

Source: MoAFCP (2013)

Most studies conclude that land fragmentation is one of the most negative consequences of the 1991 land reform (Lemel, 2000; Lusho and Papa, 1998; MoAFCP, 2007). However, none of these studies have based these arguments on empirical findings. Instead, few empirical studies have been carried in Albania to study the impacts of land fragmentation. Deininger *et al.* (2012) find no support for the argument that land fragmentation reduces productivity. The results of Sikor *et al.* (2009) instead reveal a rather counter-intuitive effect of land fragmentation – villages with more fragmented land holdings tend to have lower abandonment rates in the early transition period but no effect was observed in the later period of 1996–2003. They also found that land fragmentation increases farm productivity. The findings of Sabates-Wheeler (2002), Stahl (2007) and Zhllima *et al.* (2010) show that land fragmentation may have various economic implications for Albanian farmers. For example, Stahl (2007) found that on average a farmer needed to travel more than 6 km in order to move from one plot to the other (Stahl, 2007). Land fragmentation is often found to hamper investments in soil fertility enhancing technologies and erosion control (Nigussie *et al.*, 2017; Niroula and Thapa, 2005; Teshome *et al.*, 2014) and can limit the choice of climate adaptation measures (Kawasaki, 2010). According to some studies, land fragmentation decreases the number of alternative uses of remote plots, as remote plots are not used to plant crops that require intensive care (De Lisle, 1982; Niroula and Thapa, 2005). However, land fragmentation may lead to higher crop diversification of farm activities (Blarel *et al.*, 1992; Di Falco *et al.*, 2010) and smooth labour requirements throughout the year (Bentley, 1987; Blarel *et al.*, 1992; Fenoaltea, 1976). Heterogeneous and scattered plots can spread (climate-related) risk of production failure (Bentley, 1987; Blarel *et al.*, 1992; Fenoaltea, 1976) and may improve the soil fertility of arable land (Sklenicka and Salek, 2008). Moreover, the analysis of Zhllima *et al.* (2010) reveals that the likelihood of farmers renting out land increases with fragmentation and dispersion of land at farm level (i.e. with the average distance of the plots from farm house and a higher

[1] The authors acknowledge the financial support from the Slovak Research and Development Agency (Contract No. APVV-15-0552 and VEGA 1/0797/16). The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

number of plots per farm). Guri *et al.* (2014) conclude that land fragmentation reduces land market participation, especially in marginal areas.

Further, land fragmentation may have implications for crop rotation choices of farmers. For example, Ciaian *et al.* (2018) show in the case of Albania that land fragmentation is an important driver of production diversification which is indirectly linked to crop rotation. However, there are very few studies analysing the impact of crop rotation on farm performance in Albania (Ahmeti and Grazhdani, 2013). The available studies base their analysis mainly on agronomic experiments rather than on empirical evidence. Ahmeti and Grazhdani (2013) have observed the crop rotation effect on land productivity in south east Albania and found that crop rotation improves land productivity. The general literature on crop rotation widely supports the view that it has a positive impact on land productivity and thus also on farm performance (Havlin *et al.*, 1990; Manjunatha *et al.*, 2013).

To our knowledge there are no studies investigating the impact of both land fragmentation and crop rotation on farm performance in Albania. This paper attempts to fill this gap in the literature by estimating the impact of crop rotation and land fragmentation on farm productivity in Albania. We derive our econometric estimations from a survey data of 1018 farm households in three representative Albanian regions collected in 2013 (Guri *et al.*, 2015). This study contributes to the literature twofold: firstly, it provides an empirical estimation of the land fragmentation effects' on farm efficiency and secondly it observes farm fragmentation impact on farm productivity in association with the effect of crop rotation.

The paper is organized as follows. The next section introduces the literature review on land fragmentation and crop rotation. Section three describes the methodology of the study. Section four presents the results followed by the concluding section.

Literature review on the impacts of crop rotation and land fragmentation

There exists rather extensive literature investigating the impact of crop rotation and land fragmentation on farm performance. In general, there is a relatively wide consensus among studies that crop rotation enhances land productivity and indirectly also farm performance. Regarding land fragmentation, studies are inconclusive on its effect on farm performance.

Agronomic studies have revealed a positive impact of crop rotation on crop productivity. According to these studies, crop rotation increases crop productivity because it improves the soil fertility by retaining a higher level of organic Carbon or Nitrate (Havlin *et al.*, 1990). For example, several long term period studies have demonstrated the beneficial effect of crop rotation on yields, showing, among others, that the crop rotation increases the soil organic-matter content available for the upcoming crop which improves its yield (Havlin *et al.*, 1990; Johnston, 1986; Liebman and Dyck, 1993; Odell *et al.*, 1984). Some studies have performed economic estimations on the impact of crop rotation on farm performance. For example, Chase and Duffy (1991) and Lavoie *et al.* (1991) reveal that crop rotation is associated with positive returns to land and investment and higher farm net income. Rahman (2009) and Manjunatha *et al.* (2013) found that farmers who apply crop diversification gain in efficiency compared to farmers pursuing monoculture strategies. The monoculture strategy is accompanied in long term by water quality depletion, loss of soil fertility, water logging and salinity.

While land fragmentation has been much more frequently investigated from economic perspective, compared to crop rotation, there is a divergence in the literature on the findings regarding its impact on farm performance. Although, land fragmentation is widely perceived to be bad from the farmers' production perspective (at least from theoretical point of view), there is no full consensus among studies on whether it actually improves or worsens farm performance.

Many studies argue that land fragmented in small plots of small size has negative impact on productivity since it hampers the use of agricultural mechanics and labour causing sub-optimal application of production factors (Mwebaza and Gaynor, 2002; Penov, 2004). According to Ram *et al.* (1999), land fragmentation may drive farmers towards intensive agricultural practices such as continuous farming and monocropping, resulting in deteriorating land quality, and thus increasing production costs and lowering land productivity. All these factors ultimately are expected to adversely affect the productivity, efficiency and profitability of farms but might also have negative implications for the deployment of production factors such as labour and credit[2] (e.g. Bardhan, 1973; Corral *et al.*, 2011; Di Falco *et al.*, 2010; Jabarin and Epplin, 1994; Jha *et al.*, 2005; Kawasaki, 2010; LaTruffe and Piet, 2013; Manjunatha *et al.*, 2013; Parikh and Nagarajan, 2004; Parikh and Shah, 1994; Rahman and Rahman, 2009; Van Hung *et al.*, 2007; Wan and Cheng, 2001). However, there are cases of a lack of a statistically significant relationship between land fragmentation and farm efficiency such as that revealed in Wu *et al.* (2005).

In contrast, several studies emphasise the positive role of land fragmentation. Bentley (1987), Blarel *et al.* (1992) and Goland (1993) found that land fragmentation allows for better exploitation of land parcels by planting different crops according to plot quality, thus facilitating crop diversification, easing allocation of labour and reducing risk from harvesting failures. Sundqvist and Andersson (2007) find that land fragmentation seems to be positively correlated with productivity due to higher use of fertilisers and labour input. Moreover, according to Bentley (1987) there is a positive correlation between land fragmentation and farm performance because the splitting of farm areas into several plots facilitates crop rotation and makes it possible to leave some land fallow. Since crop harvesting times

[2] Studies found, among others, that land fragmentation reduces the possibility to apply effective irrigation and drainage systems and may lead to a loss of agricultural land surface due to excessive bunding or hedging (Mwebaza and Gaynor, 2002). Further, fragmentation reduces land value as collateral for bank loans and limits the use of modern technology (Niroula and Thapa, 2005; Tan *et al.*, 2006). The excessive level of land fragmentation increases the monitoring costs of hired labour and the occurrence of disputes between neighbouring owners (Blarel *et al.*, 1992; Sundqvist and Andersson, 2007).

differ, especially in short growing seasons and eventually when plots are at different altitudes (in mountainous areas), spreading out the labour time over the different farm activities (e.g. sawing, weeding, harvest) helps farmers to avoid labour shortages and/or hidden unemployment during the year (Bentley, 1987).

Several studies have analysed the relation between land fragmentation and crop diversity. For example, the estimates of Ciaian *et al.* (2018) show that land fragmentation is an important driver of production diversification of farm households in Albania. Similarly, Di Falco *et al.* (2010) study for Bulgaria finds that land fragmentation reduces farm profitability but fosters crop diversification, thus it indirectly increases productivity. According to Ram *et al.* (1999), land fragmentation might drive towards crop diversification, which may act as a food security[3] and farm risk reduction strategy, especially in areas suffering from natural disasters and successive droughts.

An important consideration when attempting to analyse the effects of land fragmentation is whether it is exogenous[4] (Bentley, 1987) or endogenous with respect to farmers' production related decisions (Blarel *et al.*, 1992; Van Hung *et al.*, 2007). For example, although the estimates of Latruffe and Piet (2013) suggest that land fragmentation increases production costs, reduces crop yields and decreases farm revenue and profitability, they draw attention to a possible endogeneity problem. According to Latruffe and Piet (2013), reverse causality is possible from a dynamic perspective, because efficient farms are more likely to be in a position to decrease their fragmentation at the expense of neighbouring farms. Sen (1966) meanwhile argues that land fragmentation in the case of India is an exogenous outcome rather than a cause of farm behaviour. According to this author, better quality land is concentrated in small farms, allowing farmers to attain higher output and income, which in turn allows an expansion of family members, and thus, via inheritance, leads to land fragmentation. This type of exogenous reason for land fragmentation is often relevant for countries where land structure underwent a long period of evolutionary change, but it does not explain land fragmentation in Albania. In Albania land fragmentation is an exogenous outcome of the land reform implemented in the early 1990s; it was not induced by farmers' behaviour. Recent research shows that various developments that have taken place in Albanian rural areas over last two decades (e.g. inheritance, migration, the availability of off-farm employment opportunities), may have impacted the land fragmentation but their contribution is secondary in explaining its current state (Guri *et al.*, 2011).

[3] Land fragmentation may contribute to food security of subsistence farm households if it improves production diversity improvement because it increases the variety of on-farm produced foodstuffs for household self-consumption, thus ensuring a higher likelihood of meeting nutrient requirements that can promote good health (Ciaian *et al.*, 2018; Niroula and Thapa, 2005; Tan *et al.*, 2006).

[4] The exogenous determinants of land fragmentation (mentioned also as supply-side cause factors) are usually an outcome of external factors impacting land use change such as historical influences (e.g. land reforms), geography (e.g. hilly and mountainous areas versus plain areas), population pressures (e.g. migration), inheritance (e.g. equal split land to all children versus to first-born child) or land market failures (e.g. due to government regulations, land rights insecurity) (Bentley, 1987).

Methodology

As pointed out by Greene (2012), authors have often employed a two-stage approach to estimate the determinants of farm efficiency. In the first stage, estimates of farm inefficiency are obtained without controlling for these determinants, while in the second stage, the estimated inefficiency scores are regressed against them. This approach has often been criticised for generating biased results (Wang and Schmidt, 2002). In this paper we employ simultaneous estimation to identify the impact of crop rotation and land fragmentation on farm productivity in Albania.[5]

We use a stochastic parametric approach to estimate the farm production frontier, from which output-orientated technical efficiency measures are derived. Stochastic Frontier Analysis (SFA) was originally proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977), independently of each other. Assuming the log-linear Cobb-Douglas form, the stochastic production frontier can be written as:

$$\ln y_i = \beta_0 + \sum_{n=1}^{N} \beta_n \ln X_{ni} + \varepsilon_i \tag{1}$$

where β_0 is a constant, y_i represents the output of each farm i, X_{ni} is a vector of n inputs, β_n is a vector of the parameters to be estimated, and ε_i is specified as:

$$\varepsilon_i = v_i - u_i, \qquad u_i \geq 0 \tag{2}$$

v_i captures statistical noise and u_i represents the inefficiency term. According to the original model specification, maximum likelihood estimates are obtained under these assumptions (Coelli *et al*., 2005):

$$v_i \sim iidN(0, \sigma_v^2) \tag{3}$$

$$u_i \sim iidN^+(0, \sigma_u^2) \tag{4}$$

Assumption (3) means that values of v_i are independently and identically distributed normal random variables with zero means and variances σ_u^2. Assumption (4) expresses that values of u_i are independently and identically distributed half-normal random variables with zero means and variances σ_v^2. The inefficiency effect u_i is specified as

$$u_i = \delta z_i + \omega_i \tag{5}$$

where z_i is a vector of determinants of inefficiency of farm i, δ is a vectors of parameters to be estimated and $\omega_i \geq -z_i\delta$, to ensure that $u_i \geq 0$ (Battese and Coelli, 1995). The random variable ω_i has a normal distribution with zero mean, but is truncated at 0, and has variances σ^2. Given these assumptions we can define u_i as being distributed in the non-negative truncated section of a distribution with mean $z_i\delta$ and variance σ^2, i.e. $u_i \sim N^+(z_i\delta, \sigma^2)$ (Battese and Coelli, 1995).

The motivation behind efficiency analysis is to estimate maximum feasible frontier and accordingly measure the efficiency scores of every farm relative to that frontier. In the estimation of inefficiency term, the major concern of

[5] See Belotti *et al.* (2013) for a brief overview of different model extensions based on simultaneous estimation.

researchers is to decide on the appropriate distribution function of it. Aigner *et al*. (1977) proposed half-normal, Stevenson (1980) used truncated normal, Greene (1990) preferred to use gamma, and finally Beckers and Hammond (1987) extended exponential distribution function for inefficiency component of the error term. Although, to opt for the best-fitted distribution is overwhelmingly difficult, prior theoretical insights of researchers do shape this decision making process. Coelli *et al*. (2005) underlines the notion of parsimony which is in favour of choosing the less complicated one ceteris paribus. Therefore, half-normal and exponential distributions are the best candidates which have simpler structures than other above mentioned options (Coelli *et al*., 2005: 252). In our analysis we use a number of empirical models and apply likelihood ratio tests to select the preferred model with half-normal distribution.

We use survey data collected among farm households in Albania in 2013. The survey was coordinated by the Joint Research Centre of the European Commission and it was implemented by the Agricultural University of Tirana. In total, 1,034 farm households were interviewed face-to-face in three representative agricultural regions of the country: Berat, Elbasan, and Lezhë. The sample was selected to be representative of farming systems at both national and regional level.

The selection of the regions was made by using a ranking method according three characteristics: (1) agricultural gross added value, (2) the participation to the agricultural markets and (3) land productivity. The 12 regions of Albania were divided in three groups: regions with advanced agriculture, regions with medium agricultural development and regions with less developed agriculture. Within each group the region ranked in the middle was selected for the survey. That is, Elbasan belongs to the most agriculturally advanced regions, Berat to the medium development regions, and Lezhë belongs to the least agriculturally advanced regions.

The sampling criterion used for sample selection for the three regions is based on the area distribution. That is, to select farmers in each region, the multistage sampling method was applied having as the main variable 'the surface' (Area Sampling Frame methodology). This methodology is widely used in agricultural surveys in Albania. More specifically, the following methodological steps were followed for farm selection: (1) stratification; (2) construction of primary sampling units, their numeration and selection; (3) the construction of Sample Units (segments), their selection and identification; and (4) the selection of a fixed number of farmers by activity for each selected segment. The number of selected segments for each selected region was 30 for Berat, 56 for Elbasan and 30 for the region of Lezhë. From each segment, 10 farms with agricultural activity were selected for surveying (Table 2). Figure 1 shows the selected region and the sample distribution among different municipalities of each region. After cleaning the data, the final database consists of 1,018 observations.[6]

We consider the total value of agricultural output (in national currency) to proxy the farm production in the stochastic frontier estimation (1). The total farm output was derived as a sum of the value of crop production and value of

Table 2: The number of farms selected for each selected region.

Regions	Number of farms selected
Berat	276
Elbasan	505
Lezhë	255

Source: Guri *et al.* (2015)

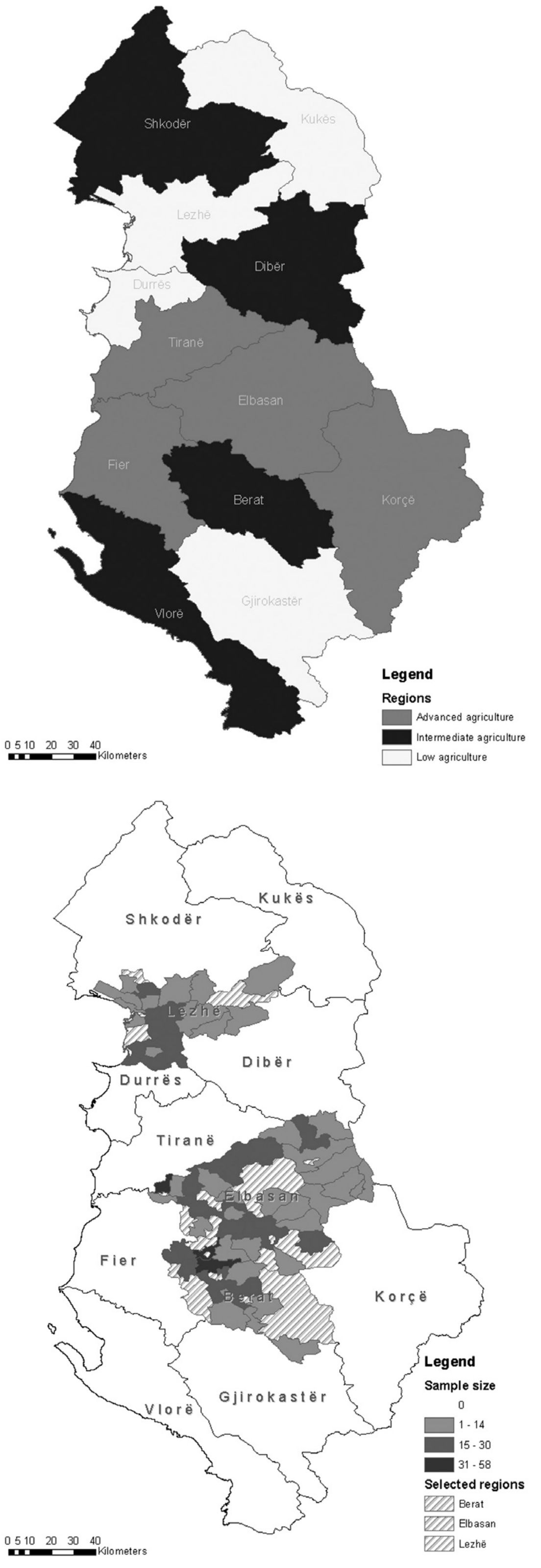

Figure 1: The classification of the regions and the distribution of the sample among the selected regions and communes.

Source: Guri *et al.* (2015)

6 For more details on sample selection see Guri *et al.* (2015).

Table 3: List of explanatory variables.

Variable	Unit	Description
gender	Dummy variable	Equals 1 if farmer is male; 0 otherwise
Age	Years	Age of farmer
marital_status	Dummy variable	Marital status of farmer (equals 1 if farmer is married; 0 otherwise (e.g. single, divorced, widow))
Education	Years	The education of farmer (years)
agri_education	Dummy variable	Agricultural education of farmer (equals 1 if farmer has agricultural education; 0 otherwise)
no_families	Number of families	Number of families living on the farm
family_member	Number of persons	Total number of family member living on the farm
Remittances	%	Share of remittances in total own funding used for to financing of agricultural activities during the agricultural year
non_agr_income_ratio	%	Non-agricultural income in in total farm production value
uaa_renting_ratio	%	Rented land in total farm land
rangeland_ratio	%	Rangeland land in total farm land
perm_crop_ratio	%	Permanent crop land in total farm land
plot_distance_farm	km	Average plot distance from the farm centre
plot_distance_market	km	Average plot distance from the nearest market or product collection facility
irrigated_uaa_ratio	%	Irrigated area in total farm land
prod_livestock_ratio	%	Livestock production in total farm production value
commercialization_ratio	%	Production sales in total farm production value
support_dum	Dummy variable	Support scheme received during the period 2007-2013 (equals 1 if farmer received support in the period 2007-2013; 0 otherwise)
Region 2	Dummy variable	Dummy variable for region 2 _
Region 3	Dummy variable	Dummy variable for region 3
plot_fragmentation	Number of plots	Number of plots
crop_rotation	Number of crops	Area weighted average number of different crops grown per a plot in the period 2011-2013 (at farm level)
rotation_fragmentation	Interaction variable	Interaction variable: crop_rotation * plot_fragmentation
crop_rotation_sq	Square variable	Square of variable plot_fragmentation
crop_rotation_sq	Square variable	Square of variable crop_rotation

Source: own composition

livestock production. Production factors are represented in the stochastic production frontier (1) by the total agricultural area in hectares, total number of (family and hired) labour days used on farm per year, the value of capital costs (e.g. irrigation, plough, sowing, weeding, spreading, harvesting, transport) and the value of variable costs (e.g. seed, fertilizers, pesticides) plus feed costs (hay, straw, stubble, grain).

The variables expected to influence inefficiency are reported in Table 1. We consider a set of explanatory variables, capturing household-specific characteristics: age (*age*), gender (*gender*), marital status of household head (*marital_status*), education of household head (*education*), agricultural education of household head (*agri_education*), number of families living in the household (*no_families*), number of household members (*family_member*), the share of remittances in total agricultural expenditure (*remittances*) and the importance of non-agricultural income (*non_agr_income_ratio*).

The second set of explanatory variables include those capturing farm characteristics: share of rented area (*uaa_renting_ratio*), the share of rangeland land (*rangeland_ratio*), share of permanent crops (*perm_crop_ratio*), share of irrigated area (*irrigated_uaa_ratio*), livestock production share (*prod_livestock_ratio*), the share of production sales in total farm production value (*commercialisation_ratio*), and the dummy variable measuring whether farm received subsidies (*support_dum*). We also consider district dummies to account for other region-specific drivers of farm efficiency (e.g., agronomic conditions, soil quality, or infrastructure).

The main variable of interest in this paper is the number of plots per farm household (*plot_fragmentation*) and the number of crops per plot (*crop_rotation*). The number of plots per farm household measures land fragmentation. The average number of crops grown per plot attempts to capture the crop rotation and it is calculated as area weighted average number of different crops grown per a plot in the period 2011-2013. It indicates the average number of crops a farm household cultivated per plot over the three years period. We also consider square variables for these two variables to account for possible non-linear effects. A negative estimated coefficient associated with the number of plots per household would indicate that the farm inefficiency decreases with the number of plots (land fragmentation). Similarly, a negative estimated coefficient associated with the average number of crops grown per plot would indicate that the farm inefficiency decreases with the number of crops (crop rotation).

Finally, the third variable of interest is the interaction term between the number of plots and the number of crops per plot (*rotation_fragmentation*). The interaction variables measure the extent to which the number of plots available on farm household together with the number of crops per plot impact farm efficiency. A negative coefficient for the interaction variable would indicate that households with a larger number of plots and greater crop rotation done on its plots have more diversified production structure.

In total, we estimate eight different model specifications to account for possible correlations between our variables of interest: land fragmentation and crop rotation. The models

Table 4: Estimated results (Dependent variable: farm inefficiency).

	M1	M2	M3	M4	M5	M6	M7	M8
gender	0.21	0.15	0.28	0.13	0.17	0.15	0.22	0.20
age	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
marital_status	-0.38 **	-0.32 **	-0.36 **	-0.28 *	-0.33 **	-0.33 **	-0.32 **	-0.28 *
education	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01
agri_education	-0.15	-0.11	-0.15	-0.12	-0.13	-0.12	-0.13	-0.13
no_families	0.03	0.01	0.01	-0.03	0.02	0.03	0.01	-0.04
family_member	-0.02	0.00	-0.02	0.01	0.01	0.01	0.01	0.01
remittances	0.01	0.01 **	0.01	0.01 **	0.01 *	0.01 *	0.01 *	0.01 *
uaa_renting_ratio	-0.15	-0.21	-0.20	-0.19	-0.25	-0.25	-0.28	-0.25
rangeland_ratio	-0.17	-0.19	-0.24	-0.19	-0.27	-0.33	-0.32	-0.31
perm_crop_ratio	-0.89 ***	-0.85 ***	-0.96 ***	-0.81 ***	-0.92 ***	-0.92 ***	-0.97 ***	-0.90 ***
plot_distance_farm	-0.01	-0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.03
plot_distance_market	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01
irrigated_uaa_ratio	-0.35 ***	-0.43 ***	-0.36 ***	-0.42 ***	-0.46 ***	-0.46 ***	-0.46 ***	-0.45 ***
prod_livestock_ratio	-2.12 ***	-1.99 ***	-2.01 ***	-1.93 ***	-1.98 ***	-1.98 ***	-1.91 ***	-1.87 ***
commercialization_ratio	-0.52 ***	-0.50 ***	-0.54 ***	-0.50 ***	-0.53 ***	-0.51 ***	-0.54 ***	-0.55 ***
non_agr_income_ratio	0.08 ***	0.07 ***	0.08 ***	0.07 ***	0.07 ***	0.07 ***	0.07 ***	0.07 ***
support_dum	1.01 ***	1.14 ***	1.04 ***	1.13 ***	1.14 ***	1.14 ***	1.15 ***	1.11 ***
Region 2	-0.28 ***	-0.32 ***	-0.27 ***	-0.30 ***	-0.33 ***	-0.34 ***	-0.32 ***	-0.28 ***
Region 3	-0.13	-0.30 ***	-0.16	-0.32 ***	-0.31 ***	-0.30 ***	-0.32 ***	-0.33 ***
plot_fragmentation		-0.13 ***		-0.36 ***	-0.13 ***	-0.29 ***	-0.12 ***	-0.39 ***
plot_fragmentation_sq				0.03 ***				0.03 ***
crop_rotation	-0.11		-1.63 ***		-0.07	-0.40 *	-1.24 **	-1.04 **
crop_rotation_sq			0.44				0.34 **	0.29 **
rotation_fragmentation						0.11 *		
Constant	2.43	2.79 ***	3.58	3.15 ***	2.85 ***	3.35 ***	3.70 ***	3.92 ***

Source: own composition.

differ in including the interaction term and the square variables for the number of plots and the number of crops per plot.

As stated by Sauer *et al.* (2012), most of the studies estimating the link between land fragmentation and efficiency have one common weak point that they do not account for the heterogeneity in farm households. We attempt to take into consideration the farm heterogeneity in agricultural production in different farm types by considering various variables that capture different production orientation such as *prod_livestock_ratio*, *range land_ratio*, *non_agr_income_ratio*, *commercialization_ratio*, etc. (Table 3).

Results

The estimation results are reported in Table 4. As mentioned above, we have estimated several models. In the first two specifications we include individually crop rotation (M1) or land fragmentation (M2) variables. The subsequent two specifications (M3, M4) consider square terms for crop rotation and land fragmentation to account for possible non-linearities. The fifth specification (M5) includes both crop rotation and land fragmentation, while the sixth model (M6) adds the interaction variable between the two variables. The last two models (M7, M8) combine square variables with both crop rotation and land fragmentation variables.

The estimates suggest that the coefficients corresponding to our variables of interest (land fragmentation and crop rotation) are statistically significant for most models (Table 4). However, the estimated coefficients corresponding to the land fragmentation appear to be more consistent across the estimated models and the significance level tends to be higher compared to the coefficients associated with the crop rotation.

The negative and significant coefficients for the land fragmentation variable (the number of plots per farm household) indicates that households with a larger number of plots attain lower inefficiency (or higher efficiency) compared to households with fewer plots. This result is consistent across all model specifications (Table 4). This result is contrary to the expectations. As explained above, land fragmentation is expected to increase operational costs of farm households because of time and energy spent by machinery and labour to move between plots leading to their sub-optimal deployment potentially causing lower productivity. The reduced possibility of farmers' operating on fragmented land to apply modern technology, to develop irrigation infrastructure or to obtain collateralised loans are also expected to cause an increase in inefficiency (Mwebaza and Gaynor, 2002; Penov, 2004). These results could be likely explained by the gains in better exploitation of household labour during the growing seasons within the year (Bentley, 1987; Blarel *et al.*, 1992; Goland, 1993). Albanian rural areas are characteristic for abundance of labour and there is evidence of hidden unemployment in rural areas in Albania (Meyer *et al.*, 2008; Zhllima *et al.*, 2016). Further, Ciaian *et al.* (2018) showed that land fragmentation leads to production diversification of farm households in Albania. In this context, land fragmentation combined with greater production diversification allows better exploitation of farm labour. By planting different crops on parcels with different labour inputs requirements across the growing season may lead to improvement of allocation and more efficient use of labour. Further, this strategy may contribute to the reduction of production risk to farmers (Bentley, 1987; Blarel *et al.*, 1992; Goland, 1993).

The variables accounting for the distance of plots from the farm house (*plot_distance_farm*) or from the market (*plot_distance_market*) are found to be statistically insignificant in affecting farm efficiency (Table 4). These two variables are also measures of land fragmentation as they measure the geographical dispersion of plots. Their statistical insignificance suggests that transport costs of inputs and goods and travelling costs of labour are not influencing the productivity. This could be due to the strategy of farmers to cultivate mainly (or to cultivate more intensively) the plots that are located near the farm thus reducing the transport costs and their impact on the productivity.

In line with expectations, our estimates suggest that crop rotation (*crop_rotation*) decreases inefficiency (or increases efficiency) of farm households (Table 4). However, the significance level and the magnitude of the estimated coefficients vary considerably across the estimated models suggesting potential correlation problem with the land fragmentation variable. The crop rotation variable is not statistically significant in specifications M1 and M5 where land fragmentation variable is excluded and included, respectively. The crop rotation variable becomes significant when interaction variable is added (M6) as well as when square variables are considered for crop rotation (M3, M7) and land fragmentation (M8). These results suggest that land fragmentation dominates the impact on farm inefficiency. Land fragmentation likely also accounts for some of the production effects of crop rotation.

The estimates show that the interaction variable between land fragmentation and crop rotation is positive and statistically significant suggesting that inefficiency increases if farms have simultaneously many plots and rotate many crops. This is also confirmed by the obtained significant coefficients for square variables. The estimated coefficients for square variables for both land fragmentation and crop rotation are positive. This implies that the land fragmentation decreases inefficiency but at decreasing rate with the number of plots. Similarly the crop rotation decreases inefficiency but at decreasing rate with the number of rotated crops (Table 4).

For the other of variables considered, the estimates show that the following ones are statistically significant in the majority of estimated models: marital status (*marital_status*), the share of permanent crops on total farm land (*perm_crop_ratio*), irrigated area (*irrigated_uaa_ratio*), livestock production share in total production (*prod_livestock_ratio*), farm commercialization (*commercialization_ratio*), non-agricultural income (*non_agr_income_ratio*), policy support (*support_dum*), remittances and regional dummies. The rest of variables not listed above (e.g., *education*, *gender*) are statistically insignificant in all estimated models (Table 4).

Non-agricultural income (*non_agr_income_ratio*) has a positive impact on the inefficiency. This result is consistent with Taylor *et al.* (2003) who also find that off-farm income reduces farm efficiency. According to Taylor *et al.* (2003), if non-agricultural income is earned from off-farm employment, part-time farms have less time to devote it for on-farm activities, substitution to hired labour is not as efficient as farm labour, and hiring agricultural labour incurs transaction costs. Also, off-farm income may be a strategy to diversify employment risks and thus it reduces the gains from specialization. Similarly, remittances also have a positive impact on the inefficiency. This could be explained by an orientation of remittances on off-farm investments. This is confirmed by Deininger *et al.* (2007) and Belletti and Leksinaj (2016) who find that remittance in rural Albania stimulate investments in off-farm business and promote off-farm activities.

A larger share of livestock production in the total household production (*prod_livestock_ratio*) is associated with a higher efficiency, potentially due to complementarities effects of the combined crop-livestock production (i.e. manure use on crops). Similarly, the combined farming systems may increase farm efficiency due to (i) more efficient use of labour across different production seasons, (ii) higher specialisation and creation of positive synergies among the activities in the farms and (iii) a more relaxed cash-flow situation within the farms – i.e. livestock products are day-to-day cash providers. For example Guri *et al.* (2016) show that the mixed crop-livestock farms have higher land productivity compared with crop or livestock farms.

As expected, the commercialization of farm households (*commercialization_ratio*) has a negative effect on their inefficiency. Farm households which sale a greater share of their production achieve higher efficiency compared to farms that produce for own consumption. The commercialization allows farm households to sustain higher productivity as it provides financial resources to purchase inputs (i.e. it alleviates credit constraint) as well as rent in land and labour. Also in line with expectations, irrigation (*irrigated_uaa_ratio*) improves farm efficiency because it raises the crop yields.

Surprisingly, the policy support (*support_dum*) reduces efficiency of farm households. This result could be explained by the fact that the full effect of the support might have not materialised yet given that most of the support in Albania is granted in the form of on-farm investment grants the impact of which often takes several years to be reflected in higher farm productivity.[7] Moreover, the support provided through on-farm investments in plantations or greenhouses increases the capital costs and operational (variable) costs, while generating small or zero production in the first years (e.g. the investment support for plantations might be in early phase of crop growth thus generating no output, or a low production level) thus leading to lower farm efficiency. The regional dummy covariates (*Region 2, Region 3*) capture any regional differences not accounted for by the other variables. The significant coefficient corresponding to these variables confirm that structural regional differences such as agronomic conditions, soil quality or quality of infrastructure have an impact on the farm household efficiency.

[7] The agricultural support was introduced in Albania less than 10 years ago and its largest share is allocated to on-farm investments such as for crop plantations, drop irrigation, wells and biomass heating, greenhouses and modernisation of farms, etc. (Zhllima and Gjeci, 2017).

Conclusions

In this paper, we have analysed land fragmentation and crop rotation and their implications for farm productivity in rural Albania. Albania represents a particularly interesting case for studying land fragmentation, as it is an outcome of land policy reform implemented in the early 1990s. The Albanian land reform led to fragmented land structures where farmers came to own several plots of different quality. We estimate stochastic production frontier to identify the impact of land fragmentation and crop rotation on farm efficiency by using survey data collected among farm households in Albania in 2013.

Our results indicate that land fragmentation is an important factor affecting the productivity of farm households in Albania. The estimates suggest that land fragmentation has improved Albanian farm efficiency, probably because it allows a better exploitation of household labour during the growing season. Our estimates also show that crop rotation has increased farm efficiency in Albania. Its influence on farm efficiency might be direct through the positive impact on land productivity (as estimated by Havlin *et al.*, 1990) or indirectly as a joint effect of land fragmentation (Ram *et al.*, 1999). The existence of crop rotation, especially in lowland regions, might reduce the vulnerabilities resulting from the monoculture and intensive use of land, which has raised concerns also in relation to water and land quality (e.g. salinity and water depletion). Moreover, it protects the farmers from the adverse effects of droughts and floods. However, our estimations suggest that the impact of crop rotation is less statistically significant than the impact of land fragmentation, which would imply that land fragmentation has a higher impact on farm inefficiency.

Our findings are consistent with the part of literature arguing a positive role of land fragmentation for farm performance. Following Bentley (1987) and Sundqvist and Andersson (2007) and considering the widespread hidden and seasonal unemployment in rural areas in Albania, our analyses support the contention that fragmentation, when associated with crop diversification, has helped to reallocate the workload across seasons (e.g. winter and summers season), between farm activities (e.g. pruning, harrowing, sawing, weeding, harvest) and among the plots (e.g. among the less distant and more distant ones). In the context of abundant labour and the prevalence of subsistence farms in rural Albania, land fragmentation allows for better exploitation of land parcels by planting different crops according to plots of different quality, thus facilitating crop diversification, easing allocation of labour, reducing the risk of harvesting failures and providing a diverse food basket for household consumption.

Overall, our results suggest that the existence of land fragmentation is less detrimental for rural growth compared to what is often perceived by the public, or among policymakers. Therefore, rather than adopting an expensive land consolidation solution to the land fragmentation problem, policy action should aim at addressing the institutional and structural barriers present in rural areas in Albania.

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Attitudes and preferences of Kosovar consumers towards quality and origin of meat

Quality and safety are important attributes for consumers in developed and transitional countries such as Kosovo. This study aims to examine Kosovar consumers' characteristics, attitude and preferences towards meat as well as to provide meat consumer profiling using a descriptive analysis together with the Food-Related Lifestyle approach. We drew a sample of 300 Kosovar consumers by means of intercept sampling in Prishtina, Prizren and Gjilan. Results suggest that Kosovar consumers perceive country of origin (COO), especially domestic origin, as an indicator of quality and safety for meat. Two consumer profiles were identified through segmentation analysis: conservative and innovative food consumers. The innovative food consumer is the most interesting target segment for Kosovar meat. There is potentially a market for meat products bearing food safety and origin labels. Therefore, private operators could consider the use of safety certification labels to signal to consumers that their products are safer than common products. The paper concludes by discussing the implications of our findings for businesses and policy makers regarding domestic meat promotion strategies.

Keywords: Consumer preferences, quality, meat, Kosovo, factor analysis, cluster analysis

JEL classifications: Q18, D12

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Introduction

In terms of Gross Domestic Product (GDP) and employment, agriculture is an important sector in Kosovo's economy. Its contribution to the annual GDP is 10.3% (KAS, 2015). Within the agriculture sector, livestock is the most important branch - it represents 44% of the total agricultural output (KAS, 2016). Livestock sales represent an important source of income for rural households. While meat is the most important livestock product, it is also one of the main food items - meat represents 19% of an average Kosovo household consumption basket (MAFRD, 2014). Meat consumption is in the range of 41 - 44 kg per capita per year (Bytyqi *et al.*, 2012; FAO, 2014). Beef and chicken meat are the most popular types of meat. In 2015, consumption of cattle meat was 18.4 kg, while that of chicken meat was 22.3 kg per capita per year (KAS, 2015; MAFRD 2016). The main beef processed products are traditional salami and prosciutto (ham). Although overall meat consumption in Kosovo is lower than the EU average, it is higher than that in other neighbouring countries. This is due to the consumption of beef and chicken, while pork consumption is insignificant, for religious and cultural reasons. As the level of income has been increasing, it is likely that meat consumption will also increase in the coming years (FAO, 2014).

Although there has been an increasing trend of livestock production in the last decade, Kosovo has not been self-sufficient in meat production and relies heavily on imports. Domestic production covers only 19% of the total annual demand. In 2015, the production of chicken meat was estimated at 2,621 tons, because the poultry sector is focused primarily towards production of eggs for consumption and chicks, while the production of chicken meat is low - imports of chicken meat were estimated at around 36,921 tons, valued at €37.4 million. Thus the domestic poultry meat production covers only a small fraction (around 6%) of the local demand. In the case of beef, the situation appears a bit better, though there is still a high dependence on imports – the level of self-sufficiency was 60% in 2015 (KAS, 2015; MAFRD, 2016). Currently, 30 companies in the industrial meat-processing sector rely mainly on imported raw meat, whilst few small traditional processors rely mostly on fresh domestic meat. The main reason is that imported raw meat, coming mainly from Brazil, Poland and the USA, is usually cheaper than the associated Kosovar products (Bytyqi *et al.*, 2012).

The government is attempting to introduce supportive policies and incentives to promote business opportunities in this field, aimed at enabling Kosovo to rely increasingly on its domestic meat in the near future. Besides improving the production side, one of the main concerns of policy makers and the industry is to understand market demand and in particular, consumer preferences for meat. What signs of quality and safety are consumers looking for? Are there any consumer preferences for domestically produced meat in Kosovo? Hence, understanding consumer preferences and perceptions is important in the decision-making of key stakeholders. Moreover, this issue is a priority for the industry, which needs to become more competitive in the local market. Despite its importance, the availability of research on Kosovo's consumer habits, preferences for and perceptions of food, particularly as regards meat, is limited. Therefore, our study aims to fill this gap by investigating Kosovar consumers' consumption habits (e.g. consumption rate, choice of shopping outlet), preferences and attitude toward different attributes of meat.

Previous research on consumer perceptions and preferences for meat in Kosovo (Bytyqi *et al.,* 2012) and Albania (a neighbouring country where meat market is similar to Kosovo) (Imami *et al.*, 2011; Zhllima *et al.*, 2015) has focused on (perceived) meat safety and quality, which are undoubtedly among the main issues that concern consumers when purchasing meat products. Therefore, we also included food safety issues in our survey. Our study confirms the findings of the above-mentioned studies with regard to consumer concerns over food safety. However, previous studies have used segmentation methods that have certain limitations (e.g. CCE or two-step cluster); our paper uses the FRL approach in connection with the meat sector in Kosovo for the first time, thus providing more insights into the consumer segmentation profile and behaviour. Furthermore, our study explores more extensively the various attributes that are perceived to be linked to food safety (and quality) by consumers.

Meat consumer behaviour has received growing attention from researchers so far (Hartmann and Siegrist, 2017; Janssen *et al*., 2016; Nesbitt *et al.*, 2014; Walley *et al.*, 2014; Walley *et al.*, 2015). Perceptions, preferences, and demand for meat with an emphasis on food safety has been the focus of many studies including Europe (e.g., Verbeke and Viaene, 1999; Becker *et al.*, 2000; Bernués *et al.,* 2003a; Bernués *et al.,* 2003b; Grunert *et al.*, 2004; Verbeke and Ward, 2006; Loureiro and Umberger, 2007; Vukasovič, 2013; Van Loo *et al.*, 2014). Consumers have become increasingly concerned about the safety of food, mainly because of several sector-wide crises in the last decade (e.g. Bovine Spongiform Encephalopaty (BSE) or mad cow disease, the dioxin crisis, classical swine fever and foot and mouth disease). Glitsch (2000) conducted a cross-national study about European consumers' perceptions of fresh meat quality in Germany, Ireland, Italy, Spain, Sweden and the UK and found that the place of beef and pork purchase is an important quality indicator at the point when consumers make a purchasing decision, while colour is the major important intrinsic quality cue for beef, pork and chicken. Freshness is regarded as a signal that warrants safety. Becker *et al.* (2000) conducted a consumer survey in Germany and found that important extrinsic cues consumers used in judging quality of fresh meat are country of origin and place of purchase, while flavour or smell are important intrinsic cues. Moreover, country of origin and freshness are of high importance for assessing safety of meat, whereas the most trusted source of information on the safety of meat is the butchery.

Owing to the limited number of previous consumer studies on Kosovo, consumer preferences and attitude toward different quality and safety attributes of meat products are our focus in this study. In order to deliver more useful information to industry, consumer segmentation analysis was conducted based on their food related lifestyle (FRL). This approach was first developed by Grunert *et al.* (1993) and Brunsø and Grunert (1995) as a mediator between consumers' values and their behaviour. Afterwards, it was applied in different cultural contexts (Brunsø *et al.*, 1995; De Boer *et al.*, 2004; Wycherley *et al.*, 2008) and tested for cross-cultural validity (Scholderer *et al.*, 2004). The FRL model aims to understand lifestyles as a cognitive construct, which explains consumer behaviour towards food (Obermowe *et al.*, 2011). A food-related lifestyle comprises of five cognitive categories, namely: ways of shopping; quality aspects for evaluating food products; cooking methods; consumption situations; and purchasing motives. The FRL approach appears to be a very useful way of segmenting food consumers (Bernués *et al.,* 2012; Escriba-Perez *et al.*, 2017; Ripoll *et al.*, 2015; Sorenson *et al.*, 2011; Thøgersen, 2017; Torrissen and Onozaka, 2017), and to the best of our knowledge, there are no published studies on the meat consumption of Kosovar consumers that use this method. Thus, this study aims to: (i) describe Kosovar consumers' characteristics, attitudes and preferences related to meat products; (ii) segment consumer groups according to their food related lifestyle; and (iii) provide insight information about Kosovar consumers' preferences for meat and suggest possible strategies for policy makers, the food industry and the marketer.

Methodology

This research was developed in the context of the FAO Project "Policy assistance to Kosovo to identify support measures linking local agricultural production with the domestic market TCP/KOS/3401" (FAO, 2014). The study combines qualitative methods (phase 1) and quantitative methods based on a structured consumer survey (phase 2).

In the qualitative research phase, expert interviews (fifteen interviews with food chain actors (e.g., wholesalers, retailers and experts) and four consumer focus groups were carried out in autumn 2013. Each focus group comprised 8-9 participants with mixed socio-economic status. The focus groups were conducted in a Hotel Meeting room in Pristina (Kosovo) based on a specific protocol/guideline developed in the project. The objectives of the focus groups were: a) obtaining information and getting a better understanding of the latest market development trends in Kosovo for the main agri-food products and b) exploring consumer preferences and purchasing behaviour for the main agri-food products that are produced in Kosovo, with the aim of eliciting useful information for the design of the structured survey.

The structured questionnaire was designed based on a literature review (as reflected in the previous section) and results from the qualitative phase. The questionnaire was structured in 7 parts: (1) general shopping habits; (2) meat consumption habits; (3) food-related lifestyle; (4) attitudes, purchasing and consumption habits for meat products; (5) price consciousness; (6) safety and quality perception toward meat products; and (7) respondent and household characteristics. In the 3rd section, a reduced version of Food Related Lifestyle (FRL) instrument proposed by Dimech *et al.* (2011) was included to segment and profile consumers. Although the full version of FRL has been used in several segmentation studies due to its consistency in results across cultures and countries, we decided to use a reduced version because the questionnaire has already contained several questions and we did not want to overload the respondents. In the reduced version, there are 5 aspects: (i) subjectivity of quality, (ii) consumer difference, (iii) intangible dimensions, (iv) information environment, and (v) price.

The questions took closed-form and multiple choices. When it came to the attitude section, respondents were asked to give their opinion toward statements according to a 5-point Likert-like scale, ranging from 1 (Strongly disagree) to 5 (Strongly agree). Respondents also had an option to skip a question, in order not to force them to reply, which might end up in incorrect answers. The draft questionnaire was pre-tested through direct interviews with consumers in Prishtina.

Data collection was conducted in Prishtina (capital city), Prizren and Gjilan – the 3 largest cities of Kosovo. The interviews were carried out face-to-face with randomly selected consumers in different parts of the town (streets, shopping centres, etc.) by trained/experienced graduates/students under the supervision of the authors of this paper. Altogether, 300 consumers were interviewed during December 2013 – January 2014. The sample structure was proportional to the population size of the three selected main urban centres. Before the interview started, interviewers asked four screening questions related to being the main household food shoppers; being the responsible for preparing/cooking food in household; being the person who decides what food to buy; and consuming meat.

Data have been analysed using both mono- and multivariate techniques by using SPSS version 24.0. A basic descriptive approach has been used to describe Kosovar consumer characteristics in terms of socio-demographics, consumption habits and perceptions toward food safety and quality of meat. Consumer groups were identified using the data contained in the FRL section of the questionnaire, by applying the classical segmentation approach. First, factor analysis was applied aimed at defining specific dimensions as useful ways to describe consumers. Afterwards, a cluster analysis method was employed, aimed at grouping the individuals according to these specifications. Finally, the resulting clusters have been evaluated according to socio-demographic and consumption habit variables and tested for differences in attitudes towards domestically produced meat.

Table 1: Socio-demographic characteristics of the sample.

Socio-demographic characteristics	Percent of total
Gender (N=297)	
Male	46.8
Female	53.2
Age (N=299) *(Mean, st.dev.)*	*40 (13.097)*
19-30 years old	29.10
31-40 years old	21.74
41-50 years old	21.40
51-60 years old	21.40
More than 60 years old	6.36
Education level (N=296) *(Median, st.dev.)*	*High school (0.745)*
Basic (4 years)	2.4
Middle (9 years)	9.1
High school (12 years)	39.2
University	49.3
Household size (N=296) *(Median, st.dev.)*	*6 members (2.075)*
2 members	1.7
3-4 members	24.0
5-6 members	39.9
7-8 members	25.3
More than 8 members	9.1
Income (N=298) *(Median, st.dev.)*	*501-800 EUR (1.311)*
150-250 EUR	9.1
251-500 EUR	30.9
501-800 EUR	32.6
801-1,200 EUR	17.1
1,201-1,500 EUR	5.0
1,501-2,000 EUR	2.7
More than 2,000 EUR	2.7
Monthly expenditure on food (N=297) *(Mean, st.dev.)*	*314 EUR (136.401)*
80-200 EUR	26.9
201-300 EUR	33.7
301-400 EUR	25.3
401-500 EUR	8.4
More than 500 EUR	5.7

Source: own data

Sample characteristics

Descriptive statistics for the socio-demographic characteristics of the sample are presented in Table 1. We found that the respondents' characteristics are consistent with the Kosovo urban census. The gender structure of the sample was quite balanced and an average respondent's age was 40 years. The majority of respondents hold a university degree (49%). Median respondents possess high school diploma (39%), while around 10% of respondents had lower education. Thus, respondents are largely educated, which is common feature of urban areas in Kosovo. Around 40% of respondents have 5-6 household members, which is also common for an average Kosovar household. The majority of respondents had household incomes between 501-800 euro/month, while the average food expenditure was 314 euro/month. However, levels of household food expenditures were quite diversified among respondents.

As to meat consumption, beef and chicken are by far the most consumed type of meat among the interviewees (Table 2). Consumption of chicken was around 2.5 kg/household/week, while consumption of beef was approximately 2.4 kg/household/week. More than 90% percent of the respondents stated that they never consumed pork (as expected, based on cultural and religious grounds). Also, small ruminants (lamb and goad-kid meat) were not consumed often (particularly goat-kid – 70% stated that they have never consumed this type of meat). Among the processed meat products,

Table 2: Meat consumption patterns in the sample.

No.	Products	N	Frequency of consumption			Average consumption (kg/week)
			Mean	Std. dev.	Median	
1.	Chicken	298	3.40	0.871	3	2.53
2.	Beef	299	3.19	1.056	3	2.37
3.	*Suxhuk* (typical local salami)	298	3.13	1.020	3	n.a.
4.	Sausages	296	2.86	1.157	3	n.a.
5.	Meatballs	298	2.72	0.991	2	n.a.
6.	Dried meat	298	2.64	1.058	2	n.a.
7.	Fish	297	2.62	0.990	2	1.17
8.	Lamb	296	1.99	0.834	2	n.a.
9.	Goat kid meat	293	1.42	0.771	1	n.a.
10.	Pork	294	1.17	0.644	1	0.09

Note: Participants were asked to rate their frequency of consumption for each meat product from never to always (1 = never, 2 = occasionally, 3 = frequently, 4 = often, 5 = always); n.a. = not applicable
Source: own calculations

suxhuk (traditional Kosovo spicy salami produced from bovine meat) was the most consumed.

As to places of shopping, results suggest that respondents prefer to buy meat products at specialized butcher's shops, followed by supermarkets and farms, respectively (Table 3). The change in lifestyle in larger urban areas is driving consumer-purchasing preference towards supermarkets; therefore, many respondents prefer to buy from supermarkets. This might be because it is more convenient, and they could buy several other things at once. However, most of the surveyed consumers still prefer to buy meat from butcher's shops (and this is especially true for beef). This confirms the view of consumers who participated in preliminary focus groups and expressed more trust in the butcher's shop to provide quality meat for them. Purchasing meat directly from farms can somehow guarantee local origin and freshness but it is less convenient; therefore, it is the least preferred shopping outlet when compared to other options.

As to food safety issues, most respondents thought that the level of food safety at different outlets was moderate, while they thought that farmer and factory had high food safety levels in general (Table 4).

Actually, it is common for most households to establish a long-lasting trust relationship with one butcher's shop. About half of the consumers tend to buy meat from the same retailer/butcher. Interestingly, many consumers would prefer to buy meat at the same place where it was slaughtered – this could be taken as a strategy for the consumer seeking a guarantee for freshness. However, this preference indicates the low level of awareness among consumers – according to safety standards, meat should not be sold or bought at the same place where animals are slaughtered. Thus, consumer understanding, information and awareness for food safety are major concerns.

Table 3: Places where consumers shopped in the sample.

No.	Outlet	N	Frequency of purchase		
			Mean	Std. dev.	Median
1.	Specialized butcher	299	3.85	0.955	4
2.	Supermarket	299	3.40	1.019	4
3.	On farm	295	3.14	1.156	3
4.	Others	118	2.12	1.163	2

Note: Participants were asked to rate their frequency of purchase at different outlets from never to always (1 = never, 2 = occasionally, 3 = frequently, 4 = often, 5 = always)
Source: own calculations

Table 4: Perceived safety level of shopping outlets for meat products.

No.	Products	Perceived level of safety		
		Mean	Std. dev.	Median
1.	Farmer	2.72	0.828	3
2.	Factory	2.63	0.934	3
3.	Supermarket	2.23	0.892	2
4.	Convenience shop	1.69	0.863	2
5.	Green market	1.62	0.946	2

Note: Participants were asked to rate their perceived safety level of each shopping outlet for meat products from very low to very high (0 = very low, 1 = low, 2 = moderate, 3 = high, 4 = very high)
Source: own calculations

Our questionnaire also included a series of questions aimed at assessing consumers' perceptions of Kosovar and foreign meat products (Table 5 and Table 6). It should be highlighted that most respondents perceived domestically produced beef and chicken to be safer and of higher quality than imported meat. However, EU origin was better perceived when compared to other foreign origin (e.g. Latin America or Serbia, which are among the main sources of imported meat). Expiry (or best before) date turned out to be the most important indicator of food safety for consumers when buying beef products. Moreover, having a food safety certificate was also perceived to be very important. Knowing the producer is considered more important than knowing the seller and brand reputation. Similar answers/preferences were stated also for chicken; however, in this case, local origin is more important than knowing the producer, while brand reputation is more important than EU origin.

Table 5: Perceptions toward safety and quality of meat in the sample.

No.	Statement	Mean	Std. dev.	Median
1.	Domestic chicken meat is safer than imported chicken meat	4.08	0.795	4
2.	Domestic beef is of high quality	4.05	0.815	4
3.	Domestic chicken meat is of high quality	4.03	0.794	4
4.	Domestic beef is safer than imported beef	4.02	0.906	4
5.	Meat is fresh if it was slaughtered less than 48 hours before and preserved in the fridge	3.84	0.932	4
6.	I prefer to buy the meat in the same place where it is slaughtered	3.47	1.07	4
7.	I always buy from the same butcher	3.41	1.111	4
8.	Imported beef is of high quality	2.62	0.991	3

Note: Participants were asked to rate their opinion toward the statements from strongly disagree to strongly agree (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree)
Source: own calculations

Table 6: Important characteristics of beef and chicken products regarding food safety in the sample.

No.	Characteristics	Beef			Chicken		
		Mean	Std. dev.	Median	Mean	Std. dev.	Median
1.	Expiry date	3.29	0.789	3	3.31	0.875	4
2.	Food safety certificate	3.04	0.862	3	3.08	0.858	3
3.	Domestic (Kosovo) origin	2.79	0.830	3	2.74	0.840	3
4.	Knowing the producer	2.69	0.937	3	2.67	0.841	3
5.	Local origin (specific place in Kosovo)	2.68	0.856	3	2.70	0.830	3
6.	EU origin	2.49	1.049	3	2.47	1.047	3
7.	Knowing the seller	2.48	0.898	2	2.44	0.888	2
8.	Brand reputation	2.44	0.891	2	2.55	0.918	2
9.	Foreign origin	1.90	0.907	2	1.98	0.949	2

Note: Participants were asked to rate the importance of each characteristics for meat from very low to very high (0 = very low, 1 = low, 2 = moderate, 3 = high, 4 = very high)
Source: own calculations

Consumer segments and profiles: the food-related lifestyle approach

In this study, we performed a segmentation analysis based on 245 consumers who answered all FRL questions including socio-demographics and consumption habits. In order to make a segmentation of Kosovar consumers using the FRL approach, we first investigated the relationship among the 18 FRL items to convert them into a smaller number of independent and easily interpretable dimensions or factors. We thus ran a Principal Component Analysis (PCA) using Promax rotation to allow correlation between dimensions. We found that three items[1] are not grouped into any factor; hence, we decided to exclude these questions and ran again the PCA with promax rotation. Prior to performing PCA, the suitability of data for factor analysis was assessed. The Kaiser-Meyer-Olkin (KMO) statistics were 0.756, which exceeded the recommended value of 0.6 (Kaiser, 1974). The Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance, thus supporting the factorability of the correlation matrix.

Table 7: Factors from Principal Components Analysis.

Items	Factor loading	Cronbach's alpha
Factor 1 (product information, sensory and awareness)		**0.698**
Product information is of high importance to me. I need to know what the product contains.	0.888	
I make a point of using natural or ecological food products	0.723	
I try to plan the amounts and types of food that the family consumes	0.598	
Eating is a matter of touching, smelling, tasting and seeing; all the senses are involved	0.488	
Before I go shopping for food, I make a list of everything I need	0.466	
I like to buy food products in specialty stores where I can get expert advice	0.424	
Factor 2 (Experimentation)		**0.585**
I like to try new types of food that I have never tasted before	0.722	
Recipes and magazines articles from other cooking traditions make me experiment in the kitchen	0.707	
Shopping for food is like an entertainment	0.650	
Factor 3 (The role of food in social life)		**0.596**
Dining with friends is an important part of my social life	0.721	
Going out for dinner is a regular part of my household eating habits	0.719	
I always plan what we are going to eat a couple of days in advance	0.709	
Factor 4 (Tradition)		**0.420**
I only buy and eat foods which are familiar to me	0.731	
I consider the kitchen to be the woman's domain	0.636	
I always check prices, even on small items	0.593	

Rotation method: Promax with Kaiser Normalization, rotation converged in six iterations; variables included in the PCA are expressed using 5-point scales
Source: own calculations

We show the variables associated with the principal components in Table 7. In the last column, Cronbach's Alpha tests are shown with values between 0.4 and 0.6. Results from the data reduction procedure suggest that in our sample, the fifteen variables analysed can be grouped into four significantly different factors, explaining 52% of the variance. Results from factor loading of each variable among the factors extracted may be associated with: (i) product information, sensory and awareness; (ii) experimentation; (iii) the role of food in the consumer's social life; and (iv) tradition.

The first factor labelled "product information, sensory and awareness" explains 24.2% of the total variance. It contains variables showing consumers' interests in getting information on the characteristics of the food that they are consuming or buying. It indicates the degree to which planning is important for the household when it comes to buying food and the planning to cook for meals. Food is for them also an involving sensory experience. The second factor labelled "experimentation" explains 11.5% of the total variance. It is linked to variables showing consumers' willingness to experience new tastes and trying out different recipes. They also love food shopping. The third factor called "the role of food in the consumer's social life" explains 8.5% of the total variance. It is related to those variables indicating that consumers view food as an important role in social life to get together with family and friends. The fourth factor, which explains 7.8% of the total variance, is labelled "tradition". It collects variables indicating preferences for familiar food and traditional approaches to cooking, including price consciousness.

Based on the four factors obtained from the PCA and the standardized score of the questions we excluded at the beginning (called "convenience", "snacks", "cooking is necessity"), we performed a cluster analysis, using a K- means clustering technique (Hair *et al.*, 2009). First, a hierarchical cluster analysis with a Ward linkage method (using Euclidean distances) was performed in order to define the optimum number of clusters. By using the K-means clustering method, two clusters were identified. Results from the cluster analysis are shown in Table 8.

The first cluster accounts for 46.12% (113 persons) of total sample and is described as "conservative food consumers". These are serious committed housekeepers who are continuing to carry on their tradition. They are price sensitive, and prefer tradition more than any another segment.

Table 8: Categories of final clusters in the sample.

Factor	Cluster 1 Conservative food consumer (N = 113)	Cluster 2 Innovative food consumer (N = 132)
Factor 1 Product information, sensory and awareness	-0.681	0.588
Factor 2 Experimentation	-0.458	0.410
Factor 3 Social life	-0.478	0.405
Factor 4 Tradition	0.005	-0.006
Factor 5 Convenience	-0.500	0.460
Factor 6 Snacks	0.330	-0.310
Factor 7 Cooking is a necessity	0.430	-0.390

Source: own calculations

[1] Question: (a) When I do not really feel like cooking, I get one of the other members of my family to do it ("convenience"); (b) In our house, nibbling has taken over and replaced set eating hours ("snacks"); (c) Cooking is a task that is best over and done with ("cooking is necessity").

As a result, this segment is not interested in challenging or innovative cooking. New products or recipes are rated the least important. Cooking for them is a necessity that has to be done. In addition, cooking is presumably the woman's job, since these consumers regard the kitchen as the woman's domain. Information on products purchased and quality attributes of products, such as, ecology and nature are given a lower priority. They snack more in comparison to the other segment.

The second cluster is called "Innovative food consumer", which accounts for 53.88% (132 persons) of the total sample. Innovative food consumers are highly interested in food from several aspects. They seek new food experience rather than simply eating out for convenience or hunger. For them, eating experience involves all sensations. Social togetherness over a meal is also important for these consumers as well as they attach an importance to eating in restaurants or together with family, friends and acquaintances. Furthermore, consumers in this segment are far more interested in new products as well as recipes in relation to the other segment. They have passion for cooking, welcome innovation together with its challenges and food shopping is a delightful activity for them. Product information is deemed very important. This segment is more interested in ecology and nature and they do not snack much. Food and related products are an important part of these consumers' lives, and are essential for social togetherness. This might explain their interesting/critical shopping behaviour, which is characterized by a strong interest in product information and quality aspects. Convenience is also important for them.

Profiling Kosovar consumer segments with socio-demographic variables

In order to understand where the differences between the segments lie and which classifying variables are significantly different between two groups, Student T-Test, Mann-Whitney U test and Chi-square test were performed. Results revealed that all factors could significantly differentiate the segments. The relationships between identified segments and socio-demographic variables were also analysed using the above-mentioned means.

The average age of respondents in Cluster 2 or Innovative food consumer (39 years old) is significantly lower than Cluster 1 or Conservative food consumer (43 years old) ($t = 2.0334$, $p = 0.022$). They have higher education as the majority of the respondents in Cluster 2 hold an university degree, while most respondents in Cluster 1 have a high school diploma ($z = 4.993$, $p < 0.001$). The average income of respondents in Cluster 2 (501-800 euro/month) is higher than that of in Cluster 1 (251-500 euro/month) ($z = 3.780$, $p < 0.001$). In addition, respondents in Cluster 1 are more price sensitive than respondents in Cluster 2 ($t = 3.9774$, $p < 0.001$).

Regarding shopping outlets for meat, respondents in Cluster 1 have significantly different preferred outlets from respondents in Cluster 2. While respondents in Cluster 2 show significantly higher preferences to purchase meat at specialized butchers ($z = 5.726$, $p < 0.001$) and on farms ($z = 3.588$, $p < 0.001$), they also show significantly lower preferences to purchase meat at supermarkets than those who are in Cluster 1 ($z = 3.124$, $p = 0.002$).

When respondents were asked to rate their perceived level of safety to buy meat products at different outlets, respondents from Cluster 1 rated supermarket as having high/very high level of safety more than respondents in Cluster 2 ($z = 3.145$, $p = 0.002$). On the contrary, respondents in Cluster 2 rated high/very high safety level of meat buying from farmers more than respondents in Cluster 1 ($z = 1.992$, $p = 0.046$).

Regarding origin of meat (PDO (Protected Designation of Origin) and PGI (Protected Geographical Indications) certifications), respondents in Cluster 2 stated they were willing to pay more for Kosovar meat from a preferred region ($z = 3.644$, $p < 0.001$) and were aware of PDO certification ($\chi2 = 7.918$, $p = 0.005$) and PGI certification ($\chi2 = 8.322$, $p = 0.004$) more than respondents in Cluster 1. Around 60% of respondents in Cluster 2 stated that they agreed or strongly agreed to pay more for meat from the preferred Kosovo region compared to 6% of respondents in Cluster 1. Around 28% and 21% of respondents in Cluster 2 were aware of PDO and PGI, while only 13% and 8% of respondents in Cluster 2 were aware of these certifications.

When respondents were asked whether they had ever bought products with PDO label, respondents from Cluster 2 responded that they did more than respondents in Cluster 1 (($\chi2 = 4.930$, $p = 0.026$). Around 19% of respondents in Cluster 2 said that they had already bought PDO products, while only 9% of respondents in Cluster 1 have ever bought them. Note that PDO and PGI concepts are relatively new for Kosovo consumers; therefore, most consumers are unaware of them.

Discussion and conclusions

The paper analysed attitudes and preferences of Kosovar consumers towards quality and origin of meat. Results suggest that consumers in Kosovo pay more attention to food safety and quality using expiration date, food safety certification, and origin, followed by trust on sellers as well as brand reputation. These results are in line with a previous study (Bytyqi *et al.*, 2012). Furthermore, our study shows that Kosovar consumers perceive country of origin (COO) and place of purchase as important cues for assessing safety of meat like consumers in other countries in Europe (similarly to Becker *et al.,* 2000 and Glitsch, 2000). Kosovar consumers prefer domestic meat (beef and chicken meat) to the imported one, as for them domestic origin is a sign of quality and safety for meat. Based on surveyed consumer preferences, there is a good chance of domestic or local meat to get a premium price from the consumers. However, information regarding expiration date, food safety certification, and origin should be provided to assist consumer decision at the selling point. Specialized butchery is still the most preferred place to buy meat. This might contribute to the fact that consumers prefer to buy meat from the trusted place where they usually can develop relationship with the seller.

Factor analysis sets out four components of FRL, defined as product information, sensory and awareness, experimentation, the role of food in the consumer's social life and tradition. Using these four factors and three additional factors (convenience, snacks, cooking is necessity), we also identified two clusters for conservative and innovative food consumers. The two clusters identified can be also used for the marketing of the product. Innovative food consumers (Cluster 2) are generally younger, and have a higher level of education and income in comparison to conservative food consumers, while the latter are more price sensitive. Innovative food consumers preferred to purchase meat at specialized butcher and on farm rather than supermarket.

In addition, we also found that the clusters identified using the FRL differ also in terms of attitudes towards Kosovar meat. Innovative food consumers express their strong preference toward domestic meat and are aware of PDO; hence, they could be a suitable target for the value-enhancement of Kosovar meat. This is confirmed by the outcome that innovative food consumers prefer to buy meat at specialized butcher and on farms rather than at supermarkets - probably as a strategy to get genuine domestic meat.

For farmers, processors and traders, our results suggest that there is a need for higher food safety levels in the meat supply chain. Similarly, there is a potential market share for meat products bearing food safety and origin labels. Therefore, private food businesses could consider using food safety and quality standards and the related certification labels to sign consumers that products are safer than the products commonly available on the market. This strategy could allow them to increase their reputation and develop trusted brands or collective labels, which can in turn become important tools to differentiate products as much as to enhance the competitiveness in the high-value market (Henson and Reardon, 2005; Roosen, 2003; Wongprawmas and Canavari, 2017).

Safety control and labelling policies should be supported to achieve food safety targets and to provide consumers with information in order to protect them from deception. Dissemination of information regarding food safety, certification and labels should be able to effectively reach consumers. However, our results show that Kosovar consumers show a "preference" for domestic meat over imported ones and they refer to Kosovo's origin as a sign of safety as well as quality of meat. This suggests that if there were (enough) domestic meat available in the market, possibly with a price comparable to the imported one, there would be high probability that Kosovar consumers would choose domestic meat.

The main limitation of our study is that since we conducted this study using a reduced version of the FRL, its comparability with other studies that used the complete FRL is limited. The Cronbach's alpha of factor 4 (Tradition) is low, but the three items load well on this factor. Therefore, future research should analyse the FRL using the full version of the instrument and compare the results with the current study. In addition, one may argue that our results are inconsistent with the current situation, since Kosovo still has a high level of imported meat consumption. Our analysis targets urban areas but it is important to point out that the situation might be somehow different in rural areas (lower purchasing power, on one hand, but also automatic consumption of farm products on the other hand). Unfortunately, no detailed secondary statistics were available to compare or complement population data with the survey sample profile. Quantitative research would be necessary to go more in-depth into consumer demand and into the issues of food safety along with origin labelling, using combined methods. Another limitation is that the survey was carried out about four years before the submission of the paper and that consequently, changes in consumer habits may have occurred during these years. However, despite the potential changes that could have taken place, it is very unlikely that the average Kosovar consumer's habits and preferences have changed drastically. Nevertheless, the reader is advised to consider the findings of this study with the time and the context within which the survey was conducted in mind, and show caution when generalizing beyond them.

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TÖRÖK Áron* and Hazel V. J. MOIR**

The market size for GI food products – evidence from the empirical economic literature

In order to understand the global importance of foods with Geographical Indications (GIs), it is essential to get an overview of the market size for such products. In spite of the relative importance of GI policy in EU trade agreements, there are only very limited data available on the actual market size for GI labelled products. Against this background this paper collects all the available data that provides estimates of the market size for GI foods, analysing the available datasets and reports of the European Commission and conducting a systematic literature review on the academic papers related to this topic. Based on the results we can underline the high level of concentration of GI products in terms of origin and product category. The most important GI market is the domestic market of the European Union even though the share of GI production is only a minor part of total agri-food output. On the other hand, GI products with both significant market size (domestic and export) and remarkable market share also exist, but these are a small set of all registered GI products and are concentrated in only a few countries.

Keywords: Geographical Indications, market size, international trade agreements, literature review, food quality schemes

JEL classifications: L15

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Introduction

Geographical Indications (GIs) are an unresolved issue in international trade agreements. Although there was at that time no definition of Geographical Indications, the different approaches of the European Union (EU) and the USA were a major area of dispute in the Uruguay Round negotiations. Earlier international treaties dealt with indications of source (Paris Convention, 1883 and Madrid Agreement, 1891) and appellations of origin (Lisbon Agreement, 1958), but the term *Geographical Indication* (GI) was first introduced in the 1994 Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, under the World Trade Organization (WTO) Agreement which resulted from the Uruguay Round negotiations.

By 2009 a system of GIs as a form of intellectual property had been established in 167 countries, the majority of them – including the EU – with a purpose-built (*sui generis*) approach, while others – like the US – with a trademark approach. The vast majority of registered GI products come from OECD member states, with the large majority being registered in the European Union (Giovannucci, Josling, Kerr, O'Connor, & Yeung, 2009)

The GI system of the EU on a community level was introduced in 1992 and revised in 2006 and 2012. It has two main components. Protected Designations of Origin (PDOs) have very similar characteristics to the already existing French Appellation d'Origine Contrôlée (AOC) and Italian Denominazione d'Origine Controllata (DOC) systems (Ilbery, Kneafsey, & Bamford, 2000; Lamarque & Lambin, 2015). Protected Geographical Indications (PGIs) have a German origin and have a strong reputational element but lesser link to *terroir* (Gangjee, 2006). The main users of EU GI policy are the Mediterranean Member States, both in terms of the number of registered products and in terms of economic importance.

The political importance of the GIs for Europe is demonstrated in its recent trade agreements (e.g. Comprehensive Economic and Trade Agreement (CETA) between the EU and Canada) and negotiations (e.g. the proposed but paused Transatlantic Trade and Investment Partnership (TTIP) between the EU and the USA) where GIs are over-represented in the text as compared to their economic importance in both domestic production and international trade. The EU has recently commenced trade negotiations with Australia and New Zealand and GIs also feature strongly in the draft texts the EU has tabled for those negotiations[1].

There are only very limited data available on the importance of GI products in the EU's agri-food industry. Based on the results of research conducted in 2010 (AND-International, 2012), the average share of GI products in the food and drink industry is less than 6% in the then 27 EU member states. Further, 60% of the GI production is sold in domestic markets. Of GI exports 91% are wines or spirits. Only a few countries – in particular, France and Italy – are the main users of this GI system. Partly because of poor data, there is as yet little analysis of the economic impact of GI policy.

The number of academic articles on GIs is large. However, most are theoretical or conceptual. Even the majority of the economic GI literature draws conclusions based only on theoretical discussion rather than empirical data. To the best of our knowledge, so far no study has attempted to synthesise the evidence-based literature on GIs.

Against this background, the aim of this paper is to estimate the size of the market for GI products, using empirically validated sources.

To do this the article focuses on GIs for agricultural and food products, including wines and spirits. All non-agriculture related products and services are excluded and are beyond the scope of this research. After a methodological introduction we analyse the market size of these GI products,

[1] http://ec.europa.eu/trade/policy/countries-and-regions/negotiations-and-agreements/. Accessed on the 19th November 2018.

focussing on the very limited public data provided by the EC, on the grey literature (also commissioned by the EC) and most importantly, on the empirical academic literature. The final part concludes.

Methodology

In order to achieve a comprehensive overview of the empirical findings on GIs, a wide online literature search was conducted using five electronic databases: JSTOR, ProQuest, Science Direct, Scopus and Web of Science. The combination of the keywords "*geographic**" and *"indication*"* were used. These search terms had to appear in the title, in the abstract, or in the keywords of the sources. In addition, the article should contain empirical data and/or analysis accompanied by information on data selection, sample size and analytic techniques that were used. We also restricted the search to articles published in English or with some information available in English.

In addition, we included key reports commissioned by the European Commission. We also reviewed the references identified in the most important articles we found and added these to our bibliography.

The initial search obtained 2,554 entries across all databases. After removing duplicates 1,854 studies were identified that might provide empirical material on GIs. To ensure that only relevant articles were included in the final analysis and to eliminate duplicates, the online software package Covidence was used. The screening and identification process is illustrated in Figure 1. Once duplicates had been removed, all articles were screened for relevance to the study. Initially this screening was undertaken independently by each author. The authors then discussed the articles where there were different screening outcomes. This initial screening led to 1,630 articles being excluded. The remaining 224 articles together with the grey literature were also each screened independently by both authors. Again this was followed by discussion of the merits of each study. At this last stage a sub-set of 111 articles which addressed the "willingness to pay a price" premium were identified, giving only an indirect estimation on GI market size; consequently, they were not included in this paper. Key GI topics not related to market size (price premium and rural development) were also excluded from this paper. Other criteria for exclusion were that the article was itself a meta-analysis – we reviewed the papers identified in these meta-analyses and added 265 articles to the dataset. Additionally we could not readily obtain sufficient information to assess some articles; others turned out not to be empirical. The final set of relevant articles with empirical material on GI market size was 20 publications from the systematic literature review with 2 additional studies from the grey literature, resulting in 22 publications altogether.

Cheese is the most frequently studied GI product. Other GI products often studied are processed meat products (mainly ham), alcohol (wine or spirit), olive oil and vegetables (Figure 2), in line with the number of products in the EU GI system (see Table 1 and Table 2 later).

As to the territorial focus of these empirical studies, the dominance of the Mediterranean countries of the EU is clearly indicated (Figure 3). Italian, French and Spanish GI products were researched most frequently. This is not surprising as these are the countries that make most use of GI labelling (see Table 2 later), though the low number of Portuguese papers is unexpected.

Market size

In the absence of official economic data, it is hard to give even an estimate of the total market size of GI products. Unlike that which exists for EU organic produce (another food quality scheme of the European Union), there is no hard economic data available in European statistics (e.g. in Eurostat).

The Farm Accountancy Data Network (FADN) system was established to measure the income level of agricultural producers in the European Union and the design does not

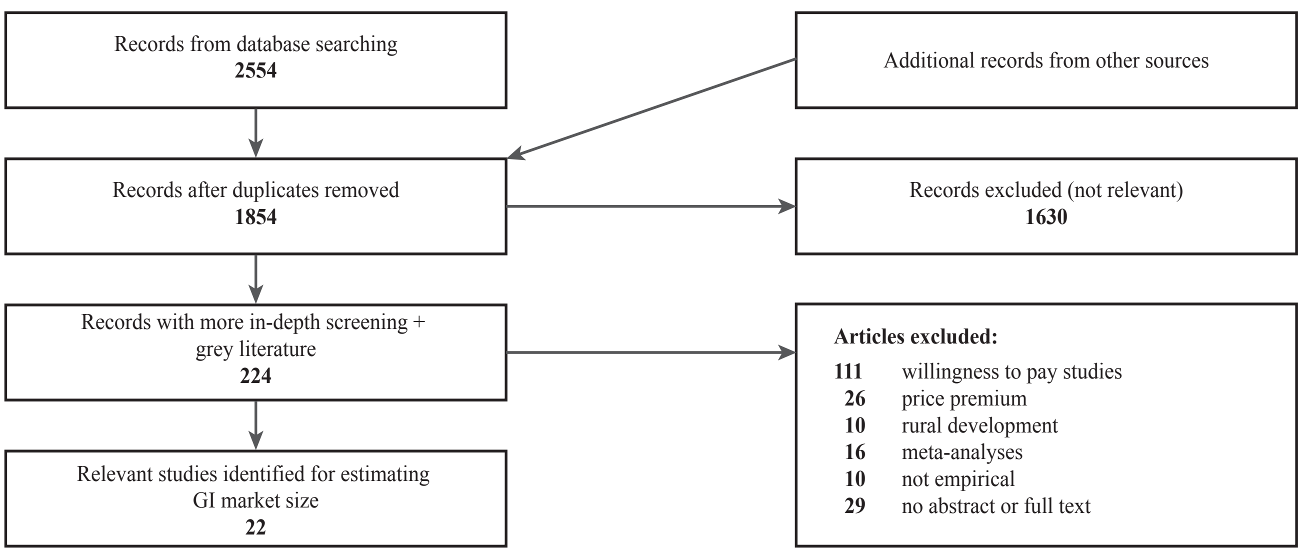

Figure 1: Process used to identify empirical GI studies on market size.
Source: own composition

allow for measurement of the effects of GI production. However, the FADN dataset is built up by summarising data gathered by national surveys conducted in the Member States, and each Member State has the opportunity to extend their national survey with additional questions. In some EU countries (e.g. in Italy, Hungary) there are some GI related data, but these are mainly limited to information about whether the producer is participating in any food quality scheme, therefore no exact estimation on the market size could be found.

Against this background we try to summarise all the information from three different sources. First, the online GI databases of the EC are summarised, giving an overview on the number of GI products. Next, the several studies conducted for the EC are investigated, while the last part collects the literature review based empirical evidences of the academic papers.

Public databases

Regarding the number of registered products, the EU has public databases for all the four GI regimes (agricultural products and foodstuffs, wines, spirits, aromatized wines) but these contain only the appellation of the product and some technical/formalities data (e.g. country of origin, type of product, date and status of the several stages of the registration process etc.).

Table 1 summarises the number of GI products, referring to the status as at 15th November 2018. Altogether 4.551 GI names are protected under the EU GI system, 74.4% of them from the European Union, and the remaining 25.6% is from outside, most dominantly wines from the USA and South-Africa. As to the share between the four GI regimes, wines together with agricultural products and foodstuffs had the most GI designations (64% and 30% respectively), while very few aromatised wines were protected.

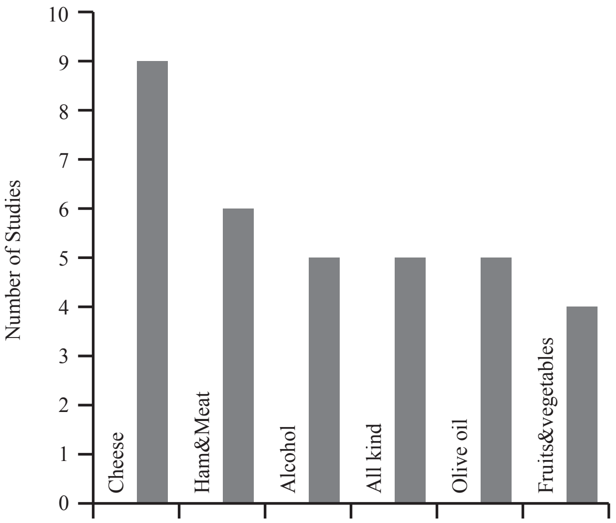

Figure 2: Products investigated.
Source: own composition

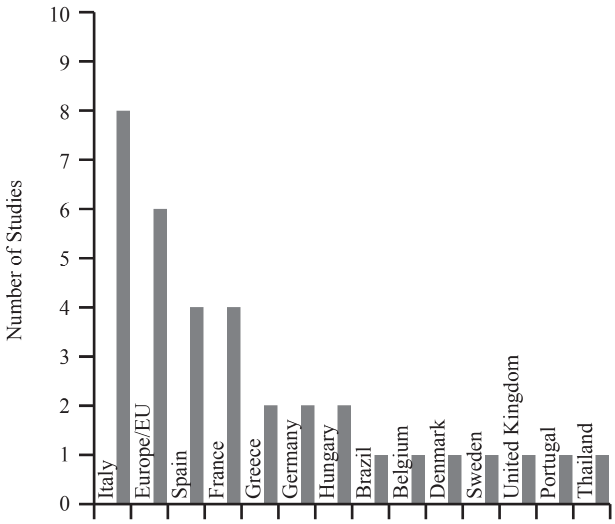

Figure 3: Territorial focus.
Source: own composition

Table 1: GI products registered under the four EU GI regimes by the 15th November 2018.

	EU		non-EU		Total	
	number of products	**share**	**number of products**	**share**	**number of products**	**share**
Agricultural products and foodstuffs	1,354	40%	26	2%	1,380	30%
Wines	1,766	52%	1,138	98%	2,905	64%
Spirits	260	8%	1	0%	261	6%
Aromatised wines	5	0%	0	0%	5	0%
Total	3,385		1,165		4,551	

Note: GI wines also includes wines with name of origin and geographical indications, both from Third Countries.
Source: EC database of DOOR (Agricultural products and foodstuffs), E-Bacchus (wines), E-Spirit-Drinks (spirits) and Register of geographical designations of aromatised drinks based on wine products (aromatised wines). All electronic databases were accessed on the 15th November 2018.

Table 2: TOP5 GI country of origin and product category in the DOOR database.

TOP5 GI country of origin			TOP5 GI product category		
country	**number of products**	**share**	**product category**	**number of products**	**share**
Italy	296	21%	Fruit, vegetables and cereals	389	28%
France	247	18%	Cheese	235	17%
Spain	192	14%	Processed meat products	177	13%
Portugal	138	10%	Fresh meat	163	12%
Greece	107	8%	Oils and fats	133	10%
Total	980	71%	Total	1,097	80%

Source: own composition based on the DOOR database (2018)

The register for agricultural products and foodstuffs is the most heterogenous category, including both uneatable agricultural outputs (e.g. hay and wool) or alcoholic drinks (beers), and also many foodstuffs. In terms of country of origin and product categories there is a very strong concentration in a few countries (Table 2). The five countries with the highest number of registered GI products are all Mediterranean EU member states, representing 71% of all registered GI products. The concentration by product categories is even more marked (80% from just five categories), including products with both low (e.g. cereals) and high (e.g. cheese or processed meat) levels of value added.

It should be kept in mind that these publicly available datasets are simple lists of registered GI names. By way of example, the UK had only one single GI spirit (Scotch Whisky) but this product alone represented the 81% of the total British GI sale in 2010, and in the same year, together with the French Cognac these two products represented 98% of total EU GI spirit exports. On the other hand, in 2010 almost every 10th European food GI name was Greek (mainly olive oils and fruits) but the GI sales value of Greece was only 2% of the total EU GI sale (AND-International, 2012)

Grey literature

In the next step we summarize the grey literature, studies done for the European Commission estimating market size of the GI products.

One of the most comprehensive reports is that done by London Economics (2008). This report pointed out that "the lack of comprehensive data on the number of PDO and PGI producers, the size of the agricultural land devoted to PDO/PGI production, the value and volume of production and the value of sales is a serious constraint to the monitoring and evaluation of the scheme at national and EU level" (p. 254). In 2018 it remains a serious constraint.

In the report the authors also ran a basic econometric model in order to test what factors influence the number of registered PDO and PGI products (and so indirectly the market size) in the EU member states. They found that the size of the total agricultural sector, strong support of the State for GI applications and being a Mediterranean country all have statistically significant positive effects on the number of GI registrations. In contrast, being a New Member State (joining the EU in 2004 or after) has a negative influence.

Building on this analysis, it is possible to compare EU Member States in terms of their relative number of GI registrations and to assess whether the share of GI registrations is higher or lower than one might expect based on population, market size (measured by GDP) or share of agricultural value added. The three right hand columns of Table 3 show this. If the value shown, for example in the most right-hand column is 1.0, this means that a country has exactly as many GIs registered as one would expect based on that country's share of EU agricultural value added. France, for example has exactly the share of GIs expected from its large agricultural sector. On the other hand, Italy has more GIs than one would expect – about 50% more. But the countries which really use the GI system far more than the size of their agricultural sector would lead one to expect are Portugal and Greece. The data in Table 3 also show clearly that other EU members are not big users of the GI system. Although Germany contributes over 10% of EU agricultural value added, it has only 7% of EU registered GIs.

Hungary, like Poland, as yet does not make much use of the EU's GI policy. Both countries substantially underuse GIs compared to all measures of size – population, GDP and agricultural value added. However, with an initiative announced in 2015 the Hungarian Government is now trying to double the number of registered GI products in the coming years, providing all the resources for the Hungarian producers registered in a national quality labelling program.

Regarding the number of GI producers/processors, only limited data were available from the London Economics report, and only for some South European countries. In Italy 3.4% of farmers and 17.7% of processors were involved in the GI industry. France had data only for farmers, and of these 14.7% were PDO and 2.9% PGI producers.

For turnover, even less data could be found: the estimates for France, Germany, Italy and Spain showed that "the contribution of the PDOs/PGIs is small but not insignificant, accounting for between 1% and 5% of the turnover of the agri-food sector" (p. 108), with around 10 billion EUR of

Table 3: Shares of GIs, GDP, population and agricultural value added

	Share of EU total				GI share of food and drink industry, 2010, %	Over-under representation of GIs vis-à-vis indicator		
	GIs by 2012, %	Population, 2012, %	GDP (PPP) 2012, %	Agricultural value added (Ag VA), 2000-07, %		pop	GDP	Ag VA
Germany	7.0	16.0	20.0	10.6	3.8	0.4	0.3	0.6
France	18.0	13.1	14.0	18.3	14.5	1.4	1.3	1.0
UK	4.8	12.7	13.4	7.6	6.2	0.4	0.3	0.6
Italy	22.1	11.9	11.9	14.9	9.5	1.9	1.9	1.5
Spain	14.8	9.3	8.6	13.3	5.7	1.6	1.7	1.1
Poland	2.0	7.7	5.0	4.7	n/a	0.3	0.4	0.5
Hungary	1.1	2.0	1.3	1.5	n/a	0.6	0.9	0.7
Greece	8.6	2.2	1.6	3.9	9.5	3.9	5.3	2.2
Portugal	10.9	2.1	1.5	2.0	8.3	5.2	7.1	5.6

Source: Moir (2016, p. 7.) Original GI data from DOORS (downloaded 26 October 2016, including all registrations filed by the end of 2012 and "registered", but excluding 17 non-European registrations). GDP and population figures from http://knoema.com; agricultural value added figures (for 2000-07 in €millions) from London Economics (2008, p. 52.); share GIs in food and drink industry from AND-International (2012, p. 24.).

GI turnover in these countries. For Greece, the Ministry of Rural Development and Food provided data for soft cheese production in 2002. The share of the PDO varieties (feta, Kasseri and Kefalograviera) among soft cheeses was more than 86% with feta dominating (79% of total Greek soft cheese production).

By far the most comprehensive research on the EU GI market was conducted by AND-International (2012). The report was commissioned by the EC and gave an overall view of all the four GI regimes in the EU. The authors used both primary (direct and indirect surveys) and secondary (centralised datasets) data.

In respect of sales value of EU GI production between 2005 and 2010 they found that wines dominate with a share of 55.9%. Agricultural products and foodstuffs represented 29.1%, and spirits 15.0%. During these years GI products had a sales value of between 48.4 and 54.3 billion EUR, with 12% growth between 2005 and 2010. Overall GI products contributed 5.7% of the total European food and drink sales value. The five most important GI products were GI wines from France, Italian foodstuffs, Italian wines, UK spirits and Spanish wines. Together these five products contributed 65% of the total sales value. The 12 most important products brought this share to 90%.

Altogether 19.5% of total GI production was exported to extra-EU markets while 20.4% was sold within the EU in 2010. For wines and spirits 87% and 64% of the total export was GI labelled, meaning that the 16% of the GI wines and 57% of GI spirit production was exported, respectively. In contrast for foodstuffs, only 2% of exports were GI labelled – that is just 6% of the total EU GI foodstuff production was sold to extra-EU markets. Exported products came mainly from France, the UK and Italy (86% of total export value), dominated by very few designations (Champagne, Cognac, Scotch Whisky, Grana Padano and Parmigiano Reggiano). The most important trade partner was the USA, followed by Switzerland, Singapore and Canada.

Overall we can say that for EU GI production the domestic market is the most important (60.1% in 2010). Intra-EU trade (20.4%) exceeds extra-EU exports (19.5%). As extra-EU exports include countries such as Switzerland, the vast majority of European GI product – especially foodstuffs – is sold within Europe.

As was already mentioned, on average 5.7% of European food output was GI labelled in 2010, but there was remarkable difference between Member States. The share of GI production in total food output exceeded 10% in France (14.5%). For Italy, Greece and Portugal the share was between 8% and 10%. In 15 Member States the share was less than 4%.

To summarise, we can conclude that European GI production is dominated by French wines, Italian wines and cheeses, German wines and beers, Spanish and Portuguese wines and Scotch Whisky.

Academic literature

Turning to the academic studies, only a few provided quantitative data on market size. While Arfini and Capelli (2009) focused on concentration in the Italian GI sector, they also provide data on market size. Italy had the highest number of PDO and PGI registrations, but only 15 designations represented 90% of Italian turnover of registered PDOs. These were mainly cheeses and processed meat products. In order to describe the economic characteristics of the Italian GI sector, they used a survey from the QUALIVITA Association and found that total Italian GI turnover was about 4,935 billion EUR (of which 85% was from PDO and 15% from PGI products), involving 119,000 firms (about 112,500 producers and 6,500 processors). PDO farms dominated, representing 89,000 firms, mainly in cheese and olive oil production. Average turnover varied between GI sectors. For meat products and cheeses, average turnover stood at 1.0 million and 1.5 million EUR respectively but other sectors were much smaller (e.g. 11,000 EUR for olive oils). Usually PGI firms had higher average turnover. They also found that Italian PDO products are sold mainly on the domestic (86%) and European markets (8%), while PGI exports are targeted more outside of Europe (e.g. 43% of PGI olive oils were sold outside of the EU).

Tibério and Francisco (2012) analysed the GI food market in Portugal finding a sales value of 70 million EUR in 2007. They found that only the 68% of registered GI output was sold in the real market, while the rest was sold via informal (undocumented) transactions and barter. Most Portuguese GI output is produced by very small scale producers.

Galli, Carbone, Caswell, and Sorrentino (2011) tried to measure the actual performance of Italian PDO cheeses, selecting 11 of the 34 registered in 2008. They found that the average turnover of an Italian PDO cheese producer in 2008 was around 50 million EUR based on 6,232 tons of production. These numbers varied a considerably between different cheeses – the biggest was Gorgonzola with 223.3 million EUR and 35,567 tons, while the smallest Murazzano with 0.2 million EUR and 22 tons of production, respectively. Concerning their market performance, a general decreasing in the period 2004 to 2008 was observed – for 6 cheeses market share fell. It is also interesting to note that the share of exports was more than 20% of total production only for three cheeses (Gorgonzola 28.5%; Pecorino Siciliano 55.5% and Pecorino Romano 83.3%).

Balogh and Jámbor (2017) investigated the European cheese industry, focusing only on the EU27 internal market as 80% of EU cheese exports is sold within the EU. Using data for these 27 countries for the period 1990 to 2013, and a GI indicator they found that the presence of a cheese PDO had a positive and significant effect on revealed comparative advantage. Thus EU countries with a registered cheese PDO had a comparative advantage over EU countries which did not.

Carbone, Caswell, Galli, and Sorrentino (2014) did an ex post assessment of the performance of Italian PDO cheese and olive oil between 2004 and 2008. They used a multi-criteria analysis framework and found that the market size performance of smaller PDO producers is better than that of bigger PDO producers as smaller producers are better connected to the place of origin and reach niche market segments. In contrast, producers of lower ranked PDO products (based on the multi-criteria analysis) target wider markets through conventional distribution channels. While their products rank lower on the multi-criteria analysis they have a higher quantity, and a larger production area and turnover.

An important issue in looking at the potential market size for GI products is the issue of how price and quantity interact. We found one study which estimated price elasticities. Monier-Dilhan, Hassan, and Orozco (2011) undertook research on the French cheese industry, focusing on 11 PDO and 10 non-PDO varieties. They used home scan data on cheese purchases in France between 1998 and 2003. Their main objective was to compare price elasticities for the different types of cheese. Price elasticities measure the extent to which volume sold varies with the price. They found that the PDO cheeses are as price elastic – or even more price elastic – than the non-PDO standard products. This means that when the price of both a PDO and a standard cheese increases, the demand for the PDO cheese decreases more than for the standard product. This also means that a price increase among PDO producers would lead to a decreasing market (share) – "consumers are not more but *less* loyal to PDOs than to standard products" (p. 17). They also found little price substitutability between the PDO and non-PDO products, though these goods (both the GI and non-GI varieties) are trademarked. Competition between the different products is therefore influenced by both the trademark reputation and the GI reputation.

As noted earlier, it is extremely complex trying to separate the influences of product quality, product origin, a GI label and a trademark label. The studies briefly reviewed here indicate the complexity and challenges of such analyses. When one then adds that GI policy applies across a vast range of different foodstuffs, with very heterogeneous characteristics, trying to find patterns in how GI policy works is challenging indeed.

A small number of studies looked specifically at GI export issues. Leufkens (2017) estimated the effects of the EU GI regulation on several trade flows using a gravity model approach and UN Comtrade data for 1996 and 2010. The results demonstrated that the EU GI system has a significant trade effect on both the intra- and extra-EU bilateral trade. The empirical results showed that, for foodstuffs only, PGI labels had a trade-creating effect, while for wines and spirits only PDOs have trade-creating effects. Surprisingly the results showed that foodstuff PDOs and wine/spirit PGIs had trade-diverting effects. These results raise complex questions for policy makers.

The most exported Tuscan PDO/PGI products were the subject of research conducted by Belletti *et al.* (2009). They found that PDO/PGI is often used as a defensive tool, but for the smaller producers it is also a marketing opportunity. From the four products included in the study, export was remarkable only for olive oils (two-thirds of production exported). PDO oils were mainly sold on EU markets (65%), while PGI oils targeted extra-EU markets (60% sold to the USA). They also found that "firms trading on foreign markets with their own brands [trademarks] show a lower interest in PDO or PGI, in order to avoid a conflict between (collective) PDO/PGI and firms' brand name" (p. 220). So this study suggests that, in practice, GI labels and trademarks are not always useful complements.

The European ham trade was investigated by Török and Jámbor (2016). They found that in the period 1999 to 2013 revealed comparative advantage in the European ham trade was affected by having a GI linked to the production area. Where the producing country had a GI recognition for its ham industry, the Revealed Symmetric Comparative Advantage index was significantly higher, indicating a comparative advantage for those producing countries (8 out of the 27 EU member states) which used GI labelling.

One study looked at European imports of GI labelled products. Wongprawmas *et al.* (2012) explored the factors affecting the opportunities for Thai GI fruit and coffee products in Europe. Europe is already an important destination for Thai tropical fruits and green coffee beans, but these products are not price competitive with comparable products from China and Vietnam. To try to gain a competitive advantage based on quality the Thai government introduced a GI system in 2008. Based on semi-structured interviews with distribution channel representatives they found that there might be a space for them in the European market, but the GI attribute alone might be not enough for the success of the product. While GI labels might help to gain the trust of importers, quality control and traceability are also very important. The study concluded that GI labelling alone would not gain market access in Europe for these Thai products.

A number of studies looked at institutional issues associated with GI markets and their potential. Bardají *et al.* (2009) analysed the Spanish beef market surveying a representative sample of retailers in Navarra. They found that geographical origin and designation of origin usually do not appear to be among the most important concerns of retailers. The results of the logistic regression showed that for the retailers, origin and appellation alone is not really important, but as their consumers prefer these logos, they sell these products.

Dentoni *et al.* (2010) analysed the market for the "Prosciutto di Parma" PDO with in-depth interviews with members of the Consortium. Even though Parma ham is one of the most well-known Italian GI products, the supply side of this market is highly heterogeneous. Smaller producers with mostly PDO production would like to have stricter regulations (controls and standards), closely following the PDO standard. In contrast, larger producers – who also have significant non-PDO production – would prefer more flexibility, using both a PGI labelled Parma ham and a PDO labelled Parma ham. As yet there has been no success in establishing a PGI registration for Parma ham.

Kizos and Vakoufaris (2011) investigated the olive oil market in Lesvos Island, Greece. In analysing the olive oil supply chain they noted the importance of self-consumption among small scale farmers (29% of the total production), and that most of the marketed olive oil is sold in bulk. Less than 1% of the total olive oil production in Lesvos Island was sold bottled with a PGI label even though the PGI olive farmers received additional payment for specific types of farming and quality production.

Tregear *et al.* (2016) conducted interviews with PDO onion producers in Hungary. Their value chain analysis gave special attention to upgrading opportunities for onions (mostly sold as a raw material), and how these farmers could capture higher margins and access to bigger markets. Like Tibério and Francisco (2012), they found that a market orientation is vital for good sales outcomes for small scale GI products. Adding more value to the onion production via diversification can be reached by building effective networks, involving regional actors external to the value chain. Cooperation with the tourism and hospitality sectors would also be beneficial for onion farmers as they might then get access to larger markets and increase their sales volume.

A number of papers focused on market size for GI labelled wines. Teuber (2011) analysed the market for a German GI apple wine, looking at both supply (single in-depth interview with producers' association) and demand (online structured questionnaire, n=741). The producer side results showed that the main reason for registering the PGI was to protect against free-riders and imitations and to prevent price erosion due to such competition. This finding is not in line with previous studies indicating that the main reason for using PGIs is to promote the product. In the case of this German apple wine the GI contribution was only to maintain the market size of the product. The consumer data indicated low awareness of the GI system and that the hypothetical willingness to pay for the product is due to consumers' expectations of a contribution to the local economy.

De Mattos *et al.* (2012), in their literature review paper, found that in case of Brazilian GI wine from the Vineyard Valley, market-driven organizations can use a PGI label to gain access to export markets and increase their export earnings. After the GI registration of the wine the number of wineries more than doubled in the protected region. This does not, of course, indicate causality, as wine sales generally were increasing at this time (2000-2011).

For Central European fruit spirits, Török and Jámbor (2013) found that GI labelled products lost their market advantages after EU accession. Using Eurostat CN8 trade data and the theory of revealed comparative advantage, they showed that while some South European GI spirits (e.g. grappa) are prospering, the majority of the Central European GI spirits have lost market share in Europe despite GI recognition.

Another trade related study used the gravity framework with Eurostat CN8 data between 1995 and 2009 to analyse the effects of GIs on quality wines exports (Agostino and Trivieri, 2014). They focused on quality wines produced in specified regions in France, Italy and Spain. In these Mediterranean countries the share of these wines in total wine export is relatively high: in France it oscillates around 60%, while Spanish and Italian shares fluctuated, reaching 40% by 2009. The average unit price of quality wines produced in the specified regions is significantly higher than the value of ordinary table wines.

These results showed that quality wines produced in specified regions have higher export values, accompanied by higher export volumes in high-income importer countries (West Europe and East Asia and Pacific, high income). These GI wines are associated with higher margins, but the higher margins vary among the producers. French wines gain a higher benefit from the GI label (both in terms of market access and price) than do their Italian and Spanish competitors.

Agostino and Trivieri (2016) also studied bilateral exports of wine from France, Italy and Spain in the period 2010-2013. They tried to measure the performance of these South European PDO, PGI and other (not GI labelled) wines in the markets of Brazil, Russia, India, China and South Africa (the BRICS countries). They concluded that wines sold with PDO labels in these markets have a high export value mainly due to the high prices of the products, especially for French wines, where PDO price premium is always the highest. For PDO products in the BRICS countries the price premium effect (505%) is higher than the volume effect (153%). PGI wines gained only a slight price premium without any positive volume effect.

Finally, one paper looked at the interaction between GI labelling and trademarks. Drivas and Iliopoulos (2017) tried to find correspondences between GI and trademark activity. Looking at 13 European countries, they found that only a very small proportion of agrifood products use the PDO/PGI system, though activity in trademarks and in GIs are strongly correlated. Both trademarks and GI labels are used for product differentiation, and both are important in accessing new markets. Products with GI/trademark labels entering new markets can use these labels to differentiate themselves from existing products on the market.

Conclusions

The outstanding finding of this study is the massive lack of relevant economic data to support GI policy. At the EU level there is no centralised data collection about GI products, except the official registration databases (DOOR, E-Bacchus, E-Spirit-Drinks). In some EU countries where the GI industry is strong enough, there are specific initiatives for GI data collection (e.g. Qualivita in Italy) at the national level, but overall we can say that there is a lack of statistical data of the GI sector across the EU. This contrasts with the situation for other food quality schemes, where easily accessible datasets are available (e.g. EUROSTAT data for organic production).

From our present perspective, the most fundamental issue is how large the market for GI foods might actually be. Based on the findings of the paper we can conclude some overall findings.

First, the share of GI production is low. Though the last comprehensive analysis has data from 2010, even in the European Union's overall food production GI had less than 6% share on average. Since that time the number of GI products increased and some exceptions exist (e.g. see the significant share of GI – Feta - in the Greek soft cheese industry), but it is likely that GI products still play a minor role in the (European) food industry. The low GI share in production is accompanied with relatively small number of GI product types: fruits and vegetables, cheeses, meats (both fresh and processed) and (olive) oils are the most often registered GI varieties.

Second, it is useful to remember that most GI-labelled foods do not travel very far – in the EU the vast majority of GI foods are sold within the country where they were produced. Only small quantities are sold outside the EU, mainly to the USA, Switzerland, Singapore and Canada. The relatively small export market is concentrated not only in terms of destination but also in terms of origin and products. The GI export of the EU mainly consists of wines, spirits and cheeses.

Third, significant differences exist between the GI producing countries. Both the domestic and external EU GI market is heavily dominated by Mediterranean European countries (mainly by France, Italy and Spain) with wider GI product portfolio, while the other countries either have only few strong GIs (e.g. Scotch whisky or German beers) or have many small designations with limited and local importance (e.g. olive oils in Greece).

All these findings are reflected in the fact that, in negotiating bilateral trade treaties, the EU seeks recognition for only a small proportion of registered GI food names. For example in CETA only 148 foodstuffs are listed in the Treaty. It is only these that will have the strong form of GI protection in Canada and there are exceptions for 8 of these products (Moir, 2017, p. 1032). The Treaty does allow for the addition of new names, but, in principle, this would not include other names registered in the EU at the time the Treaty was finalised. The main beneficiaries of the EU's GI trade negotiations are therefore a limited set of producers producing specific products from a few member states.

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The relationship between carbon dioxide emissions and Portuguese agricultural productivity

This study analyses the relationship among carbon dioxide emissions, energy consumption, agricultural labour productivity, agricultural land productivity and agricultural raw material exports using a time series for the period 1960-2015. In this article, some theroretical hypotheses are formulated, aiming to explain the bidirectional causality between agricultural productivity and climate change. These hypotheses are tested by using Vector Autoregression (VAR), Granger causality and Vector Error Correction Models (VECM). Results confirm revelant theoretical hypotheses between agricultural productivity and climate change and show that the variables used are stationary. Agricultural labour and land productivity as well as agricultural raw material exports are positively related to CO_2 emissions, meaning that these variables stimulate environmental pollution. Empirical results presented in the paper might be of interest to the academic community and also to policymakers.

Keywords: CO_2 emissions, Time Series, Agricultural Productivity, Portugal

JEL classifications: Q12, Q15

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Introduction

This paper examines the link between carbon dioxide emissions (CO_2) and Portuguese agricultural activity for the period 1960-2015. The relationship among energy consumption, agricultural labour productivity, agricultural land productivity and agricultural raw material exports are analysed by using time series models such as Unit Root Test, Vector Autoregression (VAR) and Vector Error Correction Model (VECM).

Indeed, there are numerous empirical studies that evaluate the relationship between energy consumption and growth (e.g. Altunbas and Kapusuzolu, 2011; Shahbaz *et al.*, 2013; Leitão, 2015; Leitão, 2014; Balogh and Jambor, 2017). These studies considered the arguments of the Environmental Kuznets Curve (ECK). Our research follows a different line, aiming to evaluate the impact of agricultural activity on CO_2 emissions. The literature is not unanimous in this field. Some authors, such as Asumadu-Sarkodie (2016), Filiz and Omer (2012) and Baktiari el al. (2015), have concluded that agricultural production increases the rate of environmental pollution, thereby intensifying climate change. However, there are other studies (e.g. Pant, 2009; Edoja *et al.*, 2016) concluding that agricultural productivity has a negative impact on CO_2 emissions.

Human ecology, energy economics, resource economics, international treaties and international conferences (Rio Earth Summit 1992, Kyoto Protocol 1997, Paris Agreement 2015) have alerted the international community and international economics to reduce greenhouse gas emissions, namely CO_2 emissions, accounting for most of the global warming and climate change.

This paper aims to contribute to the existing empirical literature in many ways. First, the link between energy consumption and CO_2 emissions is revisited. Second, the correlation between carbon dioxide emissions and agricultural production is also analysed. Third, assumptions are made based on the literature and they are tested by using modern econometrics techniques.

The study is structured as follows. The next section presents a literature review, followed by the demonstration of some descriptive statistics. Methodology and econometric specifications are presented in Section 4. Econometric results are presented in Section 5, while the last chapter draw some conclusions and policy recommendations.

Literature review

In this section, the most relevant literature is considered, explaining the link between agricultural productivity and environmental pollution. Literature in general has seen pollution as one of the major causes of climate change. Scientific articles in this area address this issue concerning the relationship among climate change, energy consumption, agricultural productivity, agricultural land productivity and international trade. Researchers have used different econometric approaches to analyse this issue. Empirical studies on the topic have more often used dynamic models, both concerning time series and panel data. However, as the literature review below suggests, time series using autoregressive vectors (VAR and vector error correction model - VECM) have been more frequently used because this methodology permits to estimate the causality between the variables used (see recent contributions of Asumadu-Sarkodie, 2016; Edoja *et al.*, 2016 and Ullah *et al.*, 2018).

A considerable part of the literature emphasizes the relationship between energy consumption (non renewable energy) and carbon dioxide emissions. The increase of economic activity assumes an increase in energy consumption and consequently an increase in carbon dioxide emissions. The empirical studies of Leitão and Shahbaz (2013), Leitão and Shahbaz (2016), Hamilton and Turton (2002), Friedl and Getzner (2003), Liu (2005), Ang and Liu (2001), Halicioglu (2009) as well as Jalil and Mahmud (2009) found a positive relationship between energy consumption (non-renewable energy) and CO_2 emissions, showing that energy demand has been continuously increasing in the world economy. The recent empirical studies of Mirza and Kanwal (2018) and Khobai and Roux (2017) consider the relationship between energy consumption, economic growth and carbon dioxide emissions, using time series analysis (unit root test, Granger causality, and VECM). Their econometric results show that there is causality between energy consumption and international trade. However, the empirical studies of Balogh and Jambor (2018), Kwakwa (2012), and Pant (2009) found that energy consumption is negatively related to CO_2 emissions.

Another part of the literature analyses causality between agricultural production and carbon dioxide emissions (CO_2). Such studies have been using more frequently the Ganger's causality and autoregressive vector models (VAR and VECM). In this context, carbon dioxide emissions and the agricultural ecosystem were investigated by Asumadu-Sarkodie and Owusu (2017) concerning the period 1961-2012. They have concluded that there was a bidirectional causality relationship between carbon dioxide emissions, agricultural production and non-renewable energy. The study of Khan *et al.* (2018) analyzes the relationship among agricultural productivity, energy consumption, renewable energies, forest area, vegetable area and carbon dioxide emissions from 1981 to 2015 and has shown causality between independent variables and carbon dioxide emissions (Khan *et al.*, 2018).

Ullah *et al.* (2018) analysed agricultural ecosystem and climate change in Pakistan. By using modern econometric methodologies such as Johansen cointegration and autoregressive tests, the authors proved that agricultural system was cointegrated with carbon dioxide emissions. The authors were also able to demonstrate that the use of fertilizers, energy consumption, agricultural machinery and agricultural production promoted the increase of carbon dioxide emissions. The Granger causality test found that there is a bidirectional causality between rice area and carbon dioxide emissions. The same was valid for cereal production and carbon dioxide emissions as well as crop production and carbon dioxide emissions.

The correlation between carbon dioxide emissions and the agriculture sector in Ghana was investigated by Asumadu-Sarkodie and Owusu (2016). This study compared the econometric results of Vector Error Correction Model (VECM) and Autoregressive and Distributed Lag (ARDL) model. The authors considered carbon dioxide emissions as a dependent variable and they introduced total livestock per change in area, annual change of agricultural area, total roots and tubers production, total primary vegetable production, total primary vegetables production, total pulses production, total fruit production, total coarse grain production and cocoa beans production as explanatory variables. Considering the long run results of VECM, the variables of cocoa beans production, fruit production, livestock per hectare and agricultural area showed multivariate causality with carbon dioxide emissions. All variables introduced in this regression caused carbon dioxide emissions except vegetable production. In this context, Bakhtiari *et al.* (2015) examined the relationship between energy and CO_2 emissions of saffron production using the arguments of Cobb-Douglas function and their results showed that saffron production stimulated CO_2 emissions.

However, there are studies showing that agricultural productivity is negatively correlated with carbon dioxide emissions. In fact, the empirical study of Edoja *et al.* (2016) analyzed the relationship between carbon dioxide emissions, agricultural production and food security in Nigeria for the period 1961-2010. The authors used times series analysis (unit root test, Johansen cointegration test, vector autoregressive model and Granger causality). Through unit root tests, the authors were able to demonstrate that agricultural productivity, food security and carbon dioxide emissions were stationary in first differences. The use of Johansen cointegration test showed that the variables used in this research were not in cointegration. By applying a VAR model, results showed that agricultural productivity and food security were negatively correlated with carbon dioxide emissions. However, when carbon dioxide emissions were used as the dependent variable, agricultural productivity and food security were not statistically significant as factors. The Granger causality test demonstrated an unidirectional causality between carbon dioxide emissions and agricultural productivity and food security. In this context, by using dynamic panel data, Balogh and Jambor (2017) concluded that the development of agricultural productivity contributed to a decrease in CO_2 emissions and also proved that agricultural land productivity contributed to environmental pollution growth.

The effects of agriculture on climate change were also investigated by Pant (2009). By applying a multiple regression model, results showed that agricultural land, irrigation, biomass and the efficient use of energy had a negative impact on carbon dioxide emissions. Fertilizer use had a positive effect on carbon dioxide emissions, showing that production and machinery contributed to climate change growth.

The link between international trade and environmental pollution is also analysed by the literature. In fact, the literature here is not unanimous. The dominant paradigm argues for a positive impact of trade on carbon dioxide emissions. If we consider that developed economies are concerned about climate change, then the expected signal will be negative (i.e. in this perspective, international trade discourages climate change). Mahmmood and Alkahateeb (2017) showed that trade permited to reduce pollution in Saudi Arabia, considering time series (unit root and cointegration tests). However, studies of Balogh and Jambor (2017), Shahbaz and Leitão (2013), Shahbaz *et al.* (2013) and Leitão (2015) found a positive relationship between international trade and carbon dioxide emissions. In this context, empirical studies of Amador *et al.* (2016), Andersson (2018) and Wang and Ang (2018) showed that trade liberalization and globalization accentuated global carbon dioxide emissions.

Descriptive statistics

According to the Bank of Portugal, agricultural sector represented 9% in the Portugese economy in 2015, corresponding to 35 thousand companies (Bank of Portugal, 2016), most of which were small and medium-sized enterprises (around 85%). Portuguese agricultural production is almost destined to meet domestic demand. Therefore, agricultural exports accounted only for 6% of total exports.

Table 1: Descriptive statistics for the variables used

Variable	1960	1970	1980	1990	2000	2015
CO_2 emissions (thousand kt)	8,225	14,613	25,031	41,210	64,426	45,053
Energy consumption, (kwh per capita)	320	764	1,466	2,399	3,795	4,663
Agricultural raw material exports (% of merchandise exports)	10.48	10.12	9.23	5.16	2.71	2.35
Agricultural Land Productivity in Portugal (USD/ha)	38,750	39,350	39,790	39,630	38,300	37,000

Source: own composition based on WDI (2018) data

Table 1 shows some descriptive statistics for carbon dioxide emissions, energy consumption, agricultural raw material exports and agricultural land productivity in the Portuguese economy. It is evident, for instance, that CO_2 emissions for the Portuguese economy increased from 1960 to 2000 but between 2000 to 2015, there was a decrease in air pollution, showing that the Portuguese economy was using mechanisms to reduce climate change.

According to Table 1, energy consumption was increasing in Portugal in 1960-2015, which indicates that energy demand was important for economic activity. Note that energy consumption actually grew by almost fifteen times from 1960 to 2015. Moreover, agricultural raw material exports have been declining in the period analysed. However, since the 1990s, exports have declined sharply, which shows that Portuguese agricultural production was fundamentally destined for the domestic market. Last but not least, agricultural land productivity decreased in 1960-2015, especially since the 1990s, suggesting decreasing yields.

Methodology and econometric specifications

The relationship between carbon dioxide emissions (CO_2) and Portuguese agricultural productivity is considered in this paper by using time series methods such as unit root tests, Vector Autoregression (VAR) and Vector Error Correction Model (VECM) with adjustable parameters and alpha notable. The dependent variable is CO_2 emissions, while the independent variables are energy consumption, agricultural productivity, agricultural land productivity and agricultural raw materials exports for the period 1960-2015. Granger causality test evaluates the relationship between the variables used, while the unit root test examine the stationarity between variables. If the variables are not stationary in levels, the test should be realized at the first differences. The paper also analyses the existence of cointegration by using Johansen test. Before the VAR model is applied, the test of lag order selection is used. The stability of VECM and the number of cointegration equations are considered. Moreover, the Lagrange-multiplier test checks for serial correction – VECM is stable if we do not have serial correlation. Based on the literature review, the following hypotheses are formulated.

H1: There is bidirectional causality between agricultural activity and climate change.

Research realized by Pant (2009), Cowan *et al.* (2014), Asumadu-Sarkodie (2017), Ulhah *et al.* (2018), Khan *et al.* (2018) and Jebli and Youssef (2017) proved that there was a link between agricultural activity and climate change. Thus, agricultural practices such as the use of fertilizers, stimulate global warming and CO_2 emissions. However, agricultural activity is negatively influenced by climate change and global warming.

The empirical studies of Leitão and Shahbaz (2013), Leitão and Shahbaz (2016), Hamilton and Turton (2002), Friedl and Getzner (2003), Liu (2005), Ang and Liu (2001), Halicioglu (2009) and Jalil and Mahmud (2009) showed that an increase in productivity assumes an intensification of energy consumption and subsequently an increase of CO_2 emissions. Agriculture activity is measured by agricultural labour productivity (AG) and by agricultural land productivity (LAND) – we expect a positive impact of these variables on CO_2 emissions.

H2: Non-renewable energy consumption causes CO_2 emissions.

The use of non-renewable energy (coal, oil and natural gas) is considered to be the main reason behind climate change. The use of energy causes economic growth which leads to climate change and global warming. According to the literature, there is a positive relationship between energy consumption and CO_2 emissions. The studies of Balogh and Jambor (2017), Linh and Khanh (2017), Mirza and Kanwal (2017), and Leitão and Shahbaz (2016) support to this hypothesis. Considering the contributions of Javid and Sharif (2016), Nain *et al.* (2015) and Hwang and Yoo (2014), causality exists between energy consumption and CO_2 emissions. Energy is measured by electric power consumption (kWh per capita).

H3: International trade encourages climate change.

The studies of Amador *et al.* (2018), Andersson (2018) and Wang and Ang (2018) demonstrate that international trade is associated with environmental pollution. In this context, Balogh and Jambor (2017), Shahbaz and Leitão (2013), Shahbaz *et al.* (2013) and Leitão (2015) found a positive relationship between international trade and carbon dioxide emissions. Variable for agricultural raw material exports was introduced in empirical studies, suggesting two different perspectives. The dominant paradigm considers that there is a positive relationship between international trade and carbon dioxide emissions. However, some studies argue that there is a negative relationship between this variable and carbon dioxide emissions, implying that developed economies are less polluting as they require less energy use. The variable here is measured by agricultural raw material exports as a percentage of merchandise exports.

The paper use carbon dioxide emissions (CO_2) as the dependent variable, measured in metric tons per capita and data is coming from the World Bank WDI database. Independent variables introduced in the regression are energy consumption (ENG), agricultural labour productivity (AG), agricultural land productivity (LAND) and agricultural raw materials exports (EXP). Environmental pollution (CO_2) is thought to be directly related to this function:

$$CO_2 = f\,(ENG, AG, LAND, EXP) \quad (1)$$

Mathematically, the following model is run:

$$LogCO_2 = \alpha_0 + \alpha_1 LogENG + \alpha_2 LogAG + \alpha_3 LogLAND + \alpha_4 LogEXP + ut_{it} \quad (2)$$

where *ENG* represents energy consumption, measured by electric power consumption (kWh per capita); *AG* represents agricultural labour productivity, measured as agricultural value added per worker (current USD per worker); *LAND* represents agricultural land productivity (agricultural value added per hectare in current USD per hectare) and *EXP* represents agricultural raw materials exports as a share of merchandise exports.

Table 2 summarises all independent variables used with sources and expected signs.

Table 2: List of independent variables

Variables used in this research	Expected Signs	Source
ENG - Energy consumption	[+]	World Bank
AG - Agricultural labour productivity	[+]	World Bank
LAND - Agricultural land productivity	[+]	World Bank
EXP - Agricultural raw materials exports	[+]	World Bank

Source: own composition

Table 3: Correlation between variables

	$LogCO_2$	LogENG	LogAG	Log-LAND	LogEXP
$LogCO_2$	1.000				
LogENG	0.165	1.000			
LogAG	0.352	0.635	1.000		
LogLAND	0.263	-0.522	-0.613	1.000	
LogEXP	-0.184	-0.691	-0.591	0.365	1.000

Source: own composition

Table 4: Augmented Dickey-Fuller (ADF) unit root test results

Augmented Dickey-Fuller test	ADF at Level	
Variables	Statistic	P-value
$LogCO_2$	-6.537	0.000
LogENG	-5.756	0.000
LogAG	-4.152	0.000
LogLAND	-7.005	0.000
LogEXP	-2.639	0.085

Source: own composition

Table 5: Lag order selection criteria

Lag	LL	LR	FPE	AIC	HQIC	SBIC
0	195.903	n.a.	3.5e-150	-19.090	-19.042	-18.841
1	296.831	201.860	2.0e-180	-26.683	-26.392	-25.189
2	348.800	103.940*	2.4e-190*	-29.380*	-28.846*	-26.642*

Note: LL- Lag order selected by the criterion; LR- Sequential modified; LR test statistic (each at 5% level); FPE- Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan Quinn information criterion. *: significant at 10% level.
Source: own composition.

Econometric results

The empirical results are presented in this section. We use STATA software to estimate the econometric results. Correlations between variables is showed in Table 3. The explanatory variables present a positive correlation with CO_2 emissions, except for agricultural raw materials exports. Energy consumption is positively related to agricultural labour productivity and negatively to agricultural land productivity and exports. Agricultural land productivity is positively related to agricultural exports.

Table 4 shows unit roots test for each variable used in the model, considering the Augmented Dickey-Fuller test. Results demonstrate that all variables are stationary.

Table 5 reports lag selection and order criteria. According to Table 5, a maximum of lag 2 is observable.

Table 6 presents results of the VAR model. The second lagged variable of carbon dioxide emissions [$LogCO_2$ (-2)] is statistically significant at 5% level. This result shows that climate change should be analysed in the long run. Balogh and Jambor (2017) as well as Leitão and Shahbaz (2016) also found a positive effect.

According to Table 6, agricultural labour productivity is positively related to CO_2 emissions. The second order lag [LogAG (-2)] is statistically significant at 5% level. This result is also supported by previous studies (Edoja *et al.*, 2016; Asumadu-Sarkodie and Owusu, 2016; Balogh and Jambor, 2017), showing that agricultural labour productivity encourages climate change. When the vector of energy

Table 6: Portuguese agriculture development and climate change with the VAR model

Variables	$LogCO_2$	LogENG	LogAG	LogLAND	LogEXP
$LogCO_2$(-1)	0.246 (0.237)	0.052 (0.430)	1.518** (0.001)	-0.010 (0.730)	1.959*** (0.000)
$LogCO_2$(-2)	0.429** (0.036)	-0.008 (0.901)	-0.644 (0.145)	0.036 (0.804)	1.338** (0.013)
LogENG(-1)	0.526 (0.432)	0.839*** (0.000)	-1.499 (-1.04)	0.036 (0.804)	3.173* (0.073)
LogENG(-2)	-0.747 (0.217)	0.037 (0.846)	1.536 (0.240)	-0.149 (0.257)	3.209* (0.044)
LogAG(-1)	-0.005 (0.898)	-0.006 (0.658)	-0.031** (0.002)	-0.001* (0.096)	-0.048*** (0.000)
LogAG(-2)	0.006** (0.002)	0.001** (0.002)	-0.011** (0.010)	0.002*** (0.000)	-0.002 (0.644)
LogLAND(-1)	1.832* (0.005)	0.193 (0.354)	-4.670** (0.001)	0.314** (0.028)	-6.976*** (0.000)
LogLAND(-2)	0.152 (0.742)	0.254* (0.084)	-1.665* (0.095)	-0.202** (0.045)	-3.169*** (0.009)
LogEXP(-1)	0.161** (0.021)	0.053** (0.016)	0.105 (0.485)	-0.030** (0.045)	0.674*** (0.000)
LogEXP(-2)	-0.083 (0.424)	0.002 (0.938)	-0.495** (0.028)	-0.040* (0.062)	-0.889*** (0.000)
C	-6.830* (0.043)	-1.835* (0.088)	34.951 (0.000)	4.388*** (0.000)	44.573*** (0.000)
Adj. R^2	0.960	0.990	0.760	0.930	0.770
P>chi2	0.000	0.000	0.000	0.000	0.000
Log likelihood			348.800		
AIC			-29.380		
HQIC			-28.845		
SBIC			-26.642		

Note: Statistically significant at 1%(***), 5% (**), and 10% (*). Standard errors are in parenthesis.
Source: own composition

consumption (LogENG) is observed, one can conclude that the coefficients of agricultural labour productivity, land productivity and the lagged variable of energy are statistically significant. These results demonstrate that energy consumption is necessary to agriculture activity.

Regarding the vector of agriculture labour productivity, we can infer that carbon dioxide emissions [LogCO_2 (-1)] are positively related to agricultural labour productivity. The coefficient is statistically significant at 5% level. When the first and second lag of agricultural labour productivity[LogAG(-1); LogAG(-2)] are considered, a negative sign is observable, confirming that carbon dioxide emissions are prejudicial to agricultural activity. Filiz and Omer (2012), Ullah *et al.* (2018) and Balogh and Jambor (2017) ended up in the same result.

CO_2 emissions and energy use have a positive effect on agricultural raw material exports. This result is also supported in previous studies of Leitão and Shahbaz (2013), Leitão and Shahbaz (2016), Balogh and Jambor (2017), Hamilton and Turton (2002), Friedl and Getzner (2003) and Liu (2005).

Table 7: Portuguese agricultural development and climate change with Granger causality

Null Hypothesis	Chi 2	Df	Prob > chi 2
LogCO_2 does not Granger Cause LogENG	28.914	2	0.000
LogENG does not Granger Cause LogCO_2	2.022	2	0.364
LogCO_2 does not Granger Cause LogAG	11.905	2	0.003
LogAG does not Granger Cause LogCO_2	21.168	2	0.000
LogCO_2 does not Granger Cause LogLAND	8.113	2	0.017
LogLAND does not Granger Cause Log CO_2	*1.458*	2	0.483
LogCO_2 does not Granger Cause LogEXP	6.020	2	0.049
LogEXP does not Granger Cause LogCO_2	14.550	2	0.001
LogENG does not Granger Cause LogAG	10.571	2	0.005
LogAG does not Granger Cause LogENG	3.886	2	0.143
LogENG does not Granger Cause LogLAND	4.135	2	0.127
LogLAND does not Granger Cause LogENG	108.900	2	0.000
LogLAND does not Granger Cause LogEXP	20.006	2	0.000
LogEXP does not Granger Cause LogLANG	24.920	2	0.000
LogENG does not Granger Cause LogEXP	9.909	2	0.007
LogEXP does not Granger Cause LogENG	9.988	2	0.007
LogAG does not Granger Cause LogLAND	14.677	2	0.001
LogLAND does not Granger Cause LogAND	39.520	2	0.000
LogAG does not Granger Cause LogEXP	5.548	2	0.062
LogEXP does not Granger Cause LogAG	22.244	2	0.000

Source: own composition

Table 8: VECM rank: Johansen tests for cointegration

Nº of CE(s)	LL	Eigenvalue	Trace Statistic	5% Critical value
0	205.262	n.a.	287.077	68.520
1	305.869	0.999	85.861	47.210
2	327.733	0.888	42.135	29.680
3	341.594	0.749	14.412	15.410
4	345.962	0.354	5.677	3.760
5	348.800	0.247	n.a.	n.a.

Source: own composition

Table 7 presents results of Granger causality tests, suggesting that there is causality between carbon dioxide emissions and energy consumption in line with works of Leitão and Shahbaz (2013), Leitão and Shahbaz (2016), Balogh and Jambor (2017), Hamilton and Turton (2002), Friedl and Getzner (2003), Liu (2005), Ang and Liu (2001), Halicioglu (2009) and Jalil and Mahmud (2009). It seems that there exists an unidirectional causality between CO_2 emissions and land productivity, demonstrating that increased land productivity accentuates climate change. The same conclusions is valid to energy consumption and agricultural labour productivity.

Granger causality also shows that there is a bidirectional causality between carbon dioxide emissions (LogCO_2) and agricultural labour productivity (LogAG). The same is valid for the bidirectional causality between CO_2 emissions and agricultural raw exports (LogEXP). The relationship between agricultural land productivity (LogLAND) and agricultural raw material exports (LogEXP); energy consumption (LogENG) and agricultural raw material exports (LogEXP); agricultural labour productivity (LogAG) and agricultural raw material exports (LogEXP) also present a bidirectional causality.

Moreover, the Johansen cointegration test shows that there is one cointegration relationship between all variables used in the equation in the multivariate model (Table 8).

In Table 9 and 10, results of the VECM model are presented for carbon dioxide emissions, energy consumption, agricultural labour productivity, agricultural land productivity, and agricultural raw material exports with trend, one cointegration rank, and two lags in VAR. Table 9 exhibits the adjustment parameters, while Table 10 shows estimations of adjustment parameters, considering alpha notable with trend (long-run multivariate of VECM). The coefficients of carbon

Table 9: Portuguese agricultural development and climate change with Adjustment parameters

Equation	Parms	chi2	P>chi2
DLogCO_2	1	13.664	0.057
DLogENG	1	108.281	0.000
DLogAG	1	62,211.430	0.000
DLogLAND	1	15.336	0.031
DLogEXP	1	1.392	0.985
N. of cointegration rank	1		
Max lag in VAR	2		

Source: own composition

Table 10: Portuguese agricultural development and climate change with the VEC model

alpha nobtable with trend	Coef.	Std. Err	Z	P>|z|	[95% Conf. Interval]
DLogCO_2_ce1	0.009**	0.004	2.340	0.019	0.001 0.015
DLogENG_ce1	0.009***	0.002	3.660	0.000	0.004 0.013
DLogAG_ce1	1.258***	0.006	199.590	0.000	1.245 1.270
D LogLAND_ce1	-0.003***	0.001	-2.650	0.008	-0.006 -0.001
DLogEXP_ce1	- 0.001	0.009	-0.060	0.950	-0.019 0.018

Note: Statistically significant at 1%(***); 5%(**).
Source: own composition

dioxide emissions, energy consumption, agricultural labour productivity, and agricultural land productivity are statistically significant in the first cointegration equation, with exception of agricultural raw material exports. According to the Lagrange-multiplier test, the VECM is stable.

On the whole, based on our results, neither of our hypotheses can be rejected.

Conclusions

This study analysed the relationship between carbon dioxide emissions, energy consumption, agricultural labour productivity, agricultural land productivity and agricultural raw materials exports, using time series for the period 1960-2015. A number of results were achieved as follows.

The unit root test (Augment Dickey-Fuller, ADF) showed that all variables used in this paper were stationary. Results showed that agricultural labour productivity, agricultural land productivity and agricultural raw material exports had a positive impact on CO_2 emissions (i.e. these variables increased environmental pollution). Agricultural productivity measured by two variables (agricultural labour productivity and agricultural land productivity) showed that agricultural activity stimulated global warming and CO_2 emissions. Results obtained for the variable agricultural raw materials exports were in line with the perspective that international trade fostered climate change and global warming. The empirical studies of Amador *et al.* (2016), Andersson (2018) and Wang and Ang (2018) supported these arguments.

Results also empirically proved that there existed a bidirectional causality between CO_2 emissions and agricultural raw material exports and agricultural land productivity and agricultural labour productivity. The empirical studies of Cowan *et al.* (2014), Asumadu-Sarkodie (2017), Ulhah *et al.* (2018) and Jebli, and Youssef (2017) showed that energy consumption was essential to agricultural activity; however, non-renewable energies encouraged climate change. Our results are in line with studies by Linh and Khanh (2017), Mirza and Kanwal (2017) and Leitão and Shahbaz (2016).

The Johansen cointegration test demonstrated that the multivariate model is cointegrated among all variables. Variables of carbon dioxide emissions, energy consumption, agricultural labour productivity and agricultural land productivity were statistically significant in the first cointegration equation.

It is possible to present some ideas for future work. It might be interesting to extend the research by comparing the Portuguese economy with Spain and Greece and to understand the impact of the Common Agricultural Policy on the issues analysed in the paper. It will, therefore, be necessary to understand whether or not the supply of food at lower prices stimulates climate change. This research can also be extended by incorporating new agriculture-related variables (e.g. the use of fertilizers) into the models in order to see their impacts on carbon dioxide emissions.

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Justice Gameli DJOKOTO* and Paragon POMEYIE**

Productivity of organic and conventional agriculture – a common technology analysis

The raging debate on organic versus conventional agriculture, and with regard to the aspect of productivity in particular, is far from conclusive. In this analysis, we explore the productivity comparison further through the evaluation of a common production technology used in 74 countries around the world, over the period 2005 to 2014. We found conventional agriculture to be more productive than organic agriculture. Whilst productivity of conventional agriculture is exponentially rising, that of organic is declining, although it has a quadratic growth path. For every hectare of conventional agricultural land given up, only 0.54 hectares of organic land area is substituted. Based on an elasticity of substitution of 0.36, the isoquant is relatively vertical; therefore, much more conventional lands need to be substituted with an organic land area. Research into new and improved fertilising and pest control methods is essential as positive developments there would have a significant impact on organic land productivity.

Keywords: Conventional agriculture, elasticity of substitution, land productivity, marginal rate of substitution, organic agriculture

JEL classifications: Q12, Q16

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Introduction

Researchers and policy makers alike have recognised the importance of enhancing productivity to increase agricultural output (Martin, 2013). Since the amount of arable land available is limited, desired increases in production, the goal of many countries' agricultural policy, should be met largely through increases in agricultural productivity (Hailu *et al.*, 2016). Enhanced productivity to increase agricultural output can in turn improve subsistence farmers' ability to produce more and improve the levels of household food security and income (Gallup *et al.*, 1997). Observing productivity differences between organic and conventional agriculture is therefore crucial as this has implications for efficiency, profits and subsidies, which are important for policy.

The role of productivity in the debate on conventional-organic agriculture has necessitated publications that compared productivity of conventional and organic agriculture, culminating in some reviews: Badgley *et al.* (2007), De Ponti *et al.* (2012), Ponisio *et al.* (2014), Seufert *et al.* (2012) and Lakner and Breustedt (2016, 2017). The primary studies of the review publications, published over the years, have provided mixed conclusions. Whilst some suggest that organic agriculture is more productive than conventional agriculture (e.g. Tiedemann and Latacz-Lohmann, 2011; Aldanondo-Ochoa *et al.*, 2014), most argue the contrary, namely that conventional agriculture is more productive than organic agriculture (e.g. Kumbhakar *et al.*, 2009; Mayen *et al.*, 2009; Oude Lansink *et al.*, 2002; Tiedemann and Latacz-Lohmann, 2011). However, the conclusions of the productivity comparisons were derived from studies (and or production functions) that modelled organic and conventional agriculture as different technologies[1]. Since the production technology (relations) are different, that in itself is a source of variability. Therefore, the differences in productivity found between the production practices cannot be attributed solely to the differences in production practice and may lead to inappropriate policy recommendations. To eliminate the differences attributable to production technology (different production function), in this study, we assume a common production technology for conventional and organic agriculture. By so doing, we answer the following research questions: is conventional agriculture more productive than organic agriculture? How does organic input substitute for conventional input and finally, how do these change over time?

This article primarily contributes to the literature by assuming a common production technology for organic and conventional agriculture with a separate input variable, land, for each production practice. The focus on land productivity stems from the fact that, land is a principal physical asset certified in organic production and because this is the only farm resource with publicly available data, segregated along organic and conventional production practice. The secondary contribution is to the productivity debate on conventional and organic agriculture.

The next section provides a review of some pertinent literature. The data and sources, models to estimate land productivity and associated properties of the production function are described under section 3 as methodology. Section 4 captures the results and discussions of the reported estimations. The final section is the concluding remarks.

Literature Review

Given the slightly differing approach to the analyses, and in particular, the joint evaluation of one production practice for both production technologies, literature with a similar approach to this study in respect of organic and conventional farming is rare. We therefore review some studies with a

[1] Some studies such as Breustedt *et al.* (2011), Kramol *et al.*(2010), Onumah *et al.* (2013) and Beltrán-Esteve and Reig-Martínez (2014), estimated metafrontier (common technology). However, the estimates of marginal productivity of land and other organic inputs were not segregated in the results reported. Thus, separate productivity of organic and conventional inputs were not obtainable from such common technology estimations.

bearing on our results regarding the productivity of organic and conventional agriculture.

Although uncertified organic production has been in existence for some time, certified organic agriculture is relatively recent (Bouagnimbeck, 2013; Paull, 2013a,b; Djokoto, 2015). Nevertheless, the literature space is replete with studies that have contrasted organic and conventional agriculture in some respects, including productivity and efficiency. These have resulted in a major review by Lakner and Breustedt (2016; 2017). They concluded that organic farms show a lower productivity in three of four studies (Kumbhakar *et al.*, 2009; Mayen *et al.*, 2009; Oude Lansink *et al.*, 2002; Tiedemann and Latacz-Lohmann, 2011).

Using a selectivity model to capture potential sources of a selectivity bias, Kumbhakar *et al.* (2009) found that organic dairy farms in Finland were between 21% and 37% less productive than conventional farms (depending on the estimation model). Indeed, organic farms could produce 5.3% more output by producing according to the conventional farming approach. Mayen *et al.* (2010) applied a matching model to create a 'comparable conventional group'. Their results showed that the technology of organic dairy farms in the USA was 13% less productive than the conventional technology.

Tiedemann and Latacz-Lohmann (2011) also applied a matching-model for their efficiency and productivity comparison. They showed that there was no significant differences in total factor productivity for the full period between 1999 and 2006. The organic grassland farms and organic mixed farms could both increase their productivity in the observed period. Whilst organic arable farms had a slightly higher productivity at the beginning of the observed period, they could not maintain the level of productivity by the end of the period (Tiedemann and Latacz-Lohmann, 2011).

Oude Lansink *et al.* (2002) also found organic arable and livestock farms in Finland to be 23% less productive than conventional arable farms. The study involved modelling both groups; organic and conventional agriculture separately without any strategy to accommodate the problem of selectivity. The superiority of the productivity of conventional farms has been attributed to restrictions on type of resources permitted by organic regulations, informed by principles that underpin organic agriculture and the resulting standards. These restrictions concern the type of resources and consequently the technology organic agriculture uses (Beltran-Esteve and Reig-Martinez, 2014; Mayen *et al.*, 2010).

Methodology

To obtain land productivities require the estimation of a production function to arrive at the marginal productivities of conventional and organic land as factor inputs. We therefore specified equation 1.

$$y = f(CL, OL, LA, FT, PT) \quad (1)$$

where y is output in constant 2004-2006 USD. CL is conventional land area in hectares. This was constructed as total cultivated agricultural land area less cultivated organic land area. OL is cultivated organic land area in hectares, LA is number of the persons employed in agriculture. FT is tonnes of nitrogen, phosphorus and potassium consumed and PT refer to tonnes of active ingredients of agrochemicals (excluding fertilisers) used. Equation 1 was estimated as translog and Cobb-Douglas for years 2005 to 2014 (cross-sectional) and for 2005-2014 (panel), for both ordinary least squares (OLS) and stochastic frontier analysis (SFA) (Aigner *et al.*, 1977 and Meeusen and van den Broeck, 1977), without the inefficiency effects[2].

As the study seeks to compare the productivity of organic and conventional agriculture, a rigorous comparison requires an empirical test. This was accomplished using a parameter difference test (Cohen *et al.*, 2013). The test statistic was specified as:

$$Z = \frac{MPL_{OL} - MPL_{CL}}{\sqrt{SE_{OL}^2 + SE_{CL}^2}} \quad (2)$$

where Z is the test statistic which has a normal distribution, MPL_{OL} and MPL_{CL} are marginal products of organic land and conventional land respectively. SE_{OL} and SE_{CL} are standard errors of the estimates. The specification of this standard error is based on the common error variance. The null hypothesis is that there is no statistical difference between the estimates of the marginal products.

From equation 1, marginal rate of substitution is defined as

$$MTRS_{OL,CL} = -\frac{\partial \ln y}{\partial \ln OL} \Big/ \frac{\partial \ln y}{\partial \ln CL} = -\frac{MPL_{OL}}{MPL_{CL}} \quad (3)$$

where MPL_{CL} and MPL_{OL} are conventional land productivity and organic land productivity, respectively. The $MRTS$ measures how much conventional land is given up for organic land. $MRTS_{CL,OL}$ is the slope of the isoquant and expresses how much CL decreases for a unit increase in OL (Chauhan, 2009; Jehle and Reny, 2011). The sign is negative because as CL decreases, OL increases. A high value of MRTS suggests more organic land replaces conventional land and *vice versa*.

Following the conversion of conventional land to organic certified land, an additional measure naturally emerged from equation 1 and 3; the elasticity of substitution ($\sigma_{CL,OL}$).

Mathematically:

$$\sigma_{OL,CL} = \frac{d\ln(CL/OL)}{d\ln|MTRS|} = \frac{\overline{OL}}{\overline{CL}} \cdot MRTS_{OL,CL} \quad (4)$$

where $\sigma_{OL,CL}$, the curvature of the isoquant (slope of MRTS), expresses the degree of substitution of conventional land with organic land. This follows from the calculus rule that the second order differential of a function produces the curvature of that function (Chiang and Wainwright, 2005; Jehle and Reny, 2011). A large elasticity of substitution connotes a flat isoquant and vice versa (Varian, 2006; Chauhan, 2009; Jehle and Reny, 2011; Munoz-Garcia, 2017). As long as the production function is quasi-concave, $\sigma_{OL,CL}$ can never be less than zero (Chauhan, 2009, Jehle and Reny, 2011).

[2] We avoided the estimation of inefficiency effects as it is not the focus of the article.

The data employed in the analysis may fit one form of the production function better than the other. Therefore, the two popular production functions; Cobb-Douglas and tranlog were fitted to the data and a choice was made between these, using log likelihood ratio tests.

$$D = -2 \cdot \ln \frac{Likelihood\ for\ the\ null\ model}{likelihood\ for\ the\ alternative\ model} \quad (5)$$

where D is the log likelihood statistic. In order to facilitate the time varying assessment of land productivity and the nature of substitution, cross-sectional production functions were estimated for each year, 2005 to 2014. The MRTS and $\sigma_{OL,CL}$ capture the nature of the substitution. To examine the time variance, a trend analysis was performed by fitting each indicator series to plausible functions; linear, quadratic and exponential. One function was appropriately selected based on most minimum value of mean absolute percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD). The future levels of the indicators were predicted using the selected function(s).

All data was obtained from FAOSTAT[3], except labour data that was extracted from UNCTADSTAT[4]. The FAO source of organic land area cultivated started from 2004. Number of countries with data on organic land area in 2004 was 36 and increased to 161 in 2014. In order to have 10-year period for the trend analyses, and also have appreciable number of observations, we chose to start from 2005, with 102 countries. Subsequently, all other production function variables from countries matched those of the 102 countries. However, some countries did not have corresponding data across all the variables. Eliminating these resulted in complete data on 74 countries (see Appendix). Despite the loss of 28 countries, the 74 countries (observations) per yearly cross-section, exceeded the limit of 30 required to assume normality of distributions including that of the error term.

Results and Discussion

As to descriptive statistics, mean conventional land area are in millions whilst the mean organic land area are in thousands (Table 1). Therefore, conventional land area exceeds organic land area. Mean conventional land area was constant as 26.9m ha for six out of the ten year period. However, organic land area showed more variation; rising from 201,023 ha in 2005 to 204,631 ha in 2006. The area cultivated dropped to 194,164 ha in 2007 and rose to 282,127 ha in 2011. The land area declined to 252,019 ha and rose to 292,474 ha. Thus, organic land area showed greater variability than conventional land area.

The translog functional forms for the OLS and SFA were first estimated using the panel data. However, some of the marginal products had a negative sign, contrary to theoretical requirements. More so, because objectives of the article require the use of marginal products, priority was given to conformance to theory above anything else. Cobb-Douglas functional form of OLS and SFA were then estimated and choice between these was made, using the log-likelihood ratio test. The null hypothesis that the OLS models were preferred to the SFA model could not be rejected. The choice of the Cobb-Douglas rather than the translog may have accounted for the failure to choose the SFA model. Nevertheless, the lack of inefficiency in the model was not considered to influence the marginal productivities.

Prior to discussing the results, the properties of the production functions were examined (Table 2). The adjusted R squared is above 90% with a highly significant F statistics. The production function has positive marginal products. Cobb-Douglas production functions are homogenous of degree 1 (returns-to-scale = 1), and this model conforms. The marginal products of organic and conventional land are inelastic just as the other marginal products. This seems to corroborate the OLS model being better representation of the data than the SFA.

Despite the nominal differences showing that the marginal products of organic land is less productive than con-

Table 1: Mean of various production data.

Year	Output 2004-2006 (USD)	Conventional Land (Ha)	Organic Land (Ha)	Labour (Numbers)	Fertiliser (tonnes)	Pesticides (tonnes of active ingredients)
2005	16,702,207	26,928,841	201,023	12,224,054	1,524,988	40,196
2006	17,157,846	26,928,841	204,631	12,271,297	1,551,755	38,712
2007	17,808,767	26,928,841	194,164	12,303,608	1,665,091	42,527
2008	18,521,861	26,943,913	249,384	12,342,527	1,623,833	42,808
2009	18,629,624	26,928,841	269,073	12,377,405	1,611,020	41,891
2010	19,217,730	26,928,841	268,547	12,407,149	1,762,703	45,157
2011	19,912,673	26,928,841	284,127	12,431,743	1,822,713	46,437
2012	20,201,624	27,024,695	281,919	12,450,635	1,817,663	43,714
2013	20,803,162	27,131,966	252,019	12,462,284	1,834,682	43,805
2014	21,485,057	27,127,236	291,474	12,464,946	1,892,311	46,809
2006-2014	19,044,055	26,980,086	249,636	12,373,565	1,710,676	43,206

Source: own composition based on FAO (2016) data

[3] http://www.fao.org/faostat/en/#data
[4] http://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx accessed on 25th December, 2016.

ventional land, a difference test was performed for the parameters of the panel model as well as the cross-sectional annual models. For the panel model, the test statistic of -3.88 confirms the conclusions from the nominal inspection.

The results of the cross-sectional annual model tests are similar[5]. The difference(s) between organic and conventional land productivity can be attributable to a couple of reasons. First, certified organic agriculture is relatively recent although uncertified organic production has been in existence for some time (Bouagnimbeck, 2013; Paull, 2013a, b; Djokoto, 2015). Second, the restrictions on type of resources permitted by organic regulations is informed by principles that underpin organic agriculture and the resulting standards. These restrictions relate to the type of resources and consequently the technology organic agriculture uses (Beltran-Esteve and Reig-Martinez, 2014; Mayen *et al.*, 2010). For example, synthetic fertilisers cannot be applied, pasture grazing of cattle is encouraged, and natural products are preferred to synthetic materials in pest control. In pest and disease management, there is heavy reliance on the regenerative capacity of nature for management. Thus, the limitations of the natural approaches may have resulted in lower productivity unlike for conventional agriculture. Whilst the finding of lower land productivity of organic land than conventional may partly justify subsidies, organic producers need to improve managerial capacity in order to increase their productivity. The development of processes and materials that will enhance organic land productivity is crucial in this regard. This finding is consistent with the conclusions of Lakner and Breustedt (2017).

The MRTS (penultimate line of Table 2) shows that a decrease of 1 hectare of conventional land area would result in 0.54 hectares increase of organic land, in order that output will remain unchanged. Alternatively, from equation 2, MP_{OL} constitutes 54% of MP_{CL}. This is consequential, given the low MP_{OL}. The *MRTS* of 0.54 also conveys an idea of fair gradient of the isoquant at mean level of organic and conventional land areas. The finding suggests that organic land is replacing conventional land at quite an appreciable rate. Since the *MRTS* can be increased by increasing MP_{OL} relative to MP_{CL}, stakeholders in organic agriculture need to put in more at increasing productivity of organic land (agriculture).

The elasticity of substitution (σ_{OLCL}) (last line of Table 2), which is the curvature of the isoquant, is 0.36 and is lower than the *MRTS*. This is because equation 3 shows that the σ is the *MRTS*, weighted by the ratio of organic-to-conventional land area. Since this ratio is less than 1, the σ would certainly be less than the *MRTS*. Following the fact that a large elasticity of substitution connotes a flat isoquant (Chauhan, 2009; Jehle and Reny, 2011; Munoz-Garcia, 2017), the mean value of elasticity of substitution of 0.36 connotes a relatively vertical isoquant. This is to say that, a large change in the slope of the isoquant is required in order to produce a small change in the organic-conventional land ratio. By implication, organic land would replaces conventional at a slow pace.

Following the successful estimation of the Cobb-Douglas functional form for the panel data, we disaggregated the balanced panel of 740 observations into annual cross-sections of 74 countries for 2005 to 2014, and estimated Cobb-Douglas production function for each. It is evident from Table 3 that the OLS is preferred to SFA for all the 10 estimations.

Table 4 presents the results of trend analysis. Since the quadratic model has the most of the lowest accuracy measures, it was adjudged to be the best line of fit for the MP_{OL} for the period.

Equation 6 describes time path of the MP_{OL}.

$$Y_t = 0.0908 + 0.0086\,t - 0.00072\,t^2 \qquad (6)$$

Unlike, organic, the marginal product of conventional land hikes in 2007 to 0.22 from 0.15 in 2006 (Figure 1). Although MP_{CL} also remained within a band (0.15 and 0.20), this was higher than that of the band of MP_{OL}. Within this band, MP_{CL} appear to be rising over the period 2008 to 2014. The fitted trend line, is an exponential curve (equation 7).

Table 2: Results of Cobb-Douglas estimation.

Variables	Coefficients (Standard Errors)
CL	0.191*** (0.021)
OL	0.103*** (0.009)
LA	0.246*** (0.015)
FT	0.233*** (0.013)
PT	0.131*** (0.013)
Constant	3.978*** (0.183)
Model properties	
Number of observations	740
F(5, 734)	1,399***
Adj R-squared	0.904
Returns to scale	0.905
MRTS	0.540
Elasticity of substitution (σ_{OLCL})	0.358

*** Represents 1% level of statistical significance
Source: own composition

Table 3: Loglikelihood ratio tests

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Restricted	-49.413	-49.132	-57.740	-56.549	-52.534	-55.741	-56.915	-51.731	-58.745	-56.933
Unrestricted	-49.413	-49.132	-58.040	-56.549	-52.426	-55.601	-56.735	-51.731	-58.745	-56.933
LR	4.0E-06	1.2E-05	6.0E-01	2.0E-05	-2.2E-01	-2.8E-01	-3.6E-01	1.0E-05	8.0E-06	4.0E-06
df	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Decision	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept	Accept

Source: own composition

5 These are not reported but available on request.

Table 4: Trend analysis of marginal products and substitution measures.

Accuracy measure	Linear	Quadratic	Exponential	S-curve
		MP_{OL}		
MAPE	57.427	56.850	55.784*	-
MAD	0.023	0.022*	0.030	-
MSD	0.001	0.001*	0.001	-
		MP_{CL}		
MAPE	8.225	8.104	7.927*	9.387
MAD	0.015	0.015	0.015*	0.017
MSD	0.001	0.001*	0.001	0.001
		MRTS		
MAPE	79.122	79.311	72.733*	-
MAD	0.153	0.153*	0.205	-
MSD	0.048	0.048*	0.058	-
		Elasticity of substitution		
MAPE	81.249	81.052	74.488*	-
MAD	0.102	0.102*	0.138	-
MSD	0.021	0.021*	0.026	-

MAPE-mean absolute percentage error. MAD-Mean absolute deviation. MSD-Mean squared deviation. *-lowest value among peers.
Source: own composition

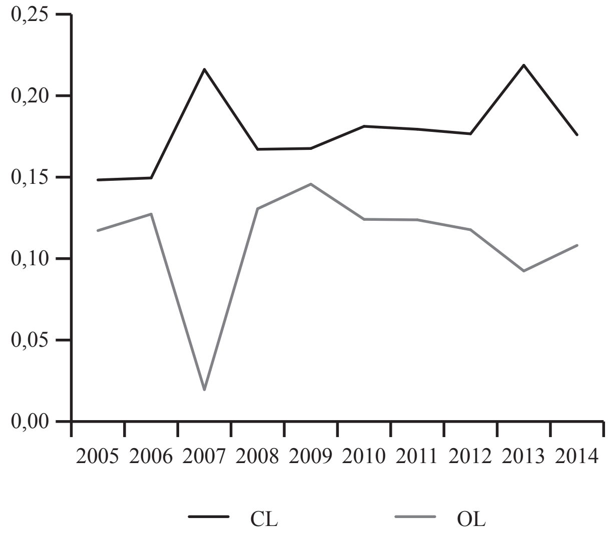

Figure 1: Time path of marginal products and trend lines.
Source: own composition

$$Y_t = 0.1573 \cdot (1.0213^t) \quad (7)$$

The substitution measures (Figure 2); MRTS and elasticity of substitution, have moved together, rising from 2005 to 2006, declined sharply in 2007, rising in 2009, then a general decline afterwards. The joint movement is not surprising as it was noted earlier that the elasticity of substitution is the organic-conventional land ratio weighting of the *MRTS*. In the case of the elasticity of substitution, over time, the curvature of the isoquant is becoming smaller and smaller, indeed, the isoquant is becoming more vertical by the year. The similarity of the substitution measures result in a quadratic trend curve for both of them.

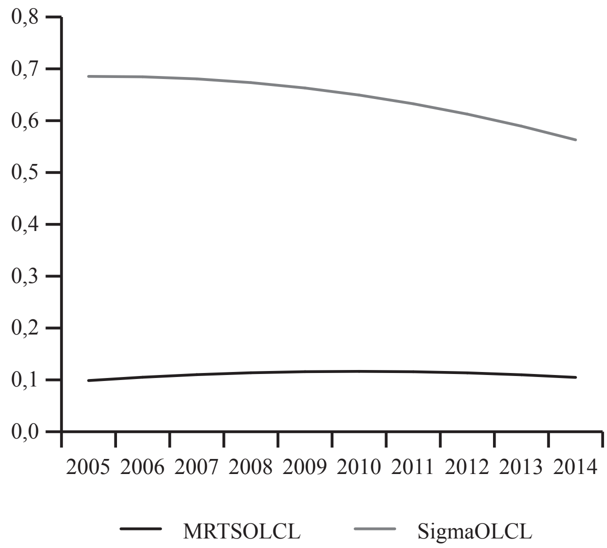

Figure 2: Substitution measures.
Source: own composition

Concluding Remarks

The raging debate on organic-conventional agriculture, and with regard to productivity in particular, is far from conclusive. This article explored the productivity comparison further, through the estimation of a common production technology for 74 countries around the world, for the period 2005 to 2014. Conventional agriculture was found to be more productive than organic agriculture. Thus, whether from different production technologies or the same, organic land is found to be less productive than conventional land.

Whilst productivity of conventional agriculture is exponentially rising, that of organic is declining, although with a quadratic growth path. For every hectare of conventional agricultural land given up, only 0.540 hectare of organic land area is substituted. Based on elasticity of substitution of 0.358, the isoquant is relatively straight (vertical), therefore, much more conventional land need to be substituted for, with organic land area. The above results require increased research in organic agriculture that would generate knowledge to increase output of organic produce. Further, new and improved fertilising and pest control productivity enhancing research is essential, as increase in these, would have a significant impact on land productivity. This would contribute to increased efficiency. Increased land productivity means more output per unit of land cultivated, therefore more profit as there will be less currency cost per unit of output, particularly as certification fees are partly based on land area certified. The level of marginal rate of substitution and elasticity of substitution demands re-invigoration of the promotion of organic technology by stakeholders in the organic movement.

An interesting question that could not be addressed is, what is the optimal input ratio (organic-conventional land) that will enable the production technology attain at least constant returns-to-scale? Had the translog function been appropriate, this could have been established by the Ray (1998) approach. Further research can explore this.

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Appendix: List of countries

Algeria	France	Norway
Argentina	Germany	Panama
Armenia	Ghana	Poland
Austria	Greece	Portugal
Azerbaijan	Guatemala	Republic of Korea
Belgium	Guyana	Romania
Belize	Honduras	Rwanda
Bhutan	Hungary	Slovenia
Bolivia (Plurinational State of)	Iceland	Spain
Brazil	India	Sri Lanka
Burkina Faso	Ireland	Sweden
Burundi	Italy	Switzerland
Canada	Jordan	Thailand
Chile	Kyrgyzstan	The former Yugoslav Republic of Macedonia
China, mainland	Latvia	Timor-Leste
Colombia	Lithuania	Togo
Costa Rica	Madagascar	Turkey
Croatia	Malawi	Ukraine
Cyprus	Malaysia	United Kingdom
Czechia	Mali	Uruguay
Denmark	Mexico	
Dominican Republic	Mozambique	
Egypt	Nepal	
El Salvador	Netherlands	
Estonia	New Zealand	
Fiji	Nicaragua	
Finland	Niger	

Source: own composition

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The impact of traditional and non-traditional agricultural exports on the economic growth of Peru: a short- and long-run analysis

This study aims to analyze and quantify the short- and long-run impact of agricultural exports–both traditional and non-traditional products–on economic growth of Peru using an annual time series data from 2000 to 2016 obtained from the Central Bank of Peru and the World Bank. Traditional agricultural exports value, non-traditional agricultural exports value, labor force and fixed capital formation value for each year of the stipulated period were used as determinant factors of the economic growth. A Vector Autoregression (VAR) Model, Augmented Dickey-Fuller (ADF) test, Johansen Co-integration test and Granger Causality test were employed for data analysis. The findings revealed that in the short run, traditional agricultural exports have had a positive but non-significant effect on economic growth while non-traditional agricultural exports have had a positive and significant effect on Gross Domestic Product (GDP). Meanwhile, both fixed capital formation and the labor force have had a significant effect on the GDP, albeit in different directions. The ADF test showed that, with the exception of traditional agricultural exports and fixed capital formation, all determinants became stationary at a level I (0). Moreover, the Co-integration result showed that there is a long-run relationship between the studied variables and a unidirectional causality in the relation between the determinant variables and economic growth.

Keywords: Peru, agricultural exports, economic growth, fixed capital formation, labor force

JEL classifications: F1, F14, F47, Q17

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Introduction

Exports as the driving engine of the economy is a widely accepted notion in the field of development economics. Exports influence and contribute to the growth and development of a national economy through a variety of channels. An increase in a country's export of goods and services can reduce unemployment, improve the balance of payments, increase foreign exchange earnings, and reduce pressure on external borrowing (Chenery and Strout, 1966). Exports enhance workers' pay, benefits, skills and productivity; they enhance corporate innovation and stability; and they benefit workers and owners of small businesses, as well as large ones (Richardson and Rindal, 1995). Furthermore, exports can be a source of learning and technological externalities for the home economy and allow domestic producers to learn from sophisticated markets abroad. An increase in exports is a conduit through which a country can foster economic growth (Mabeta, 2015).

Substantial growth of agricultural exports has been one of the outstanding characteristics of many Latin American economies since the 1990s (Damiani, 2000). Peru, a dynamic Latin American economy, has significantly expanded its role as a global food supplier in recent years. Traditionally known mostly for its exports of metals and mineral ores, the country's agriculture exports have recently grown at an average annual rate of 12.5%; its value increased from US$ 758 million in 2000 to more than US$ 5.78 billion in 2016 (the World Bank, 2017). Peru groups its agricultural exports into traditional and non-traditional products. Peru's traditional agricultural exports include coffee, cocoa, cotton and sugar. As international prices for these traditional agriculture exports have fallen in recent years, so has their relative importance, compared with the new, non-traditional agricultural exports (Meade *et al.*, 2010). This decline notwithstanding, the country's non-traditional agriculture exports, which mainly include grapes, asparagus, avocado, quinoa, banana and many other fruits, have taken up the slack (Oxford Business Group, 2016). From a base of $925m in 2000, exports of non-traditional agriculture products have grown at 10-15% per annum, surpassing US$ 5bn in 2016 (Oxford Business Group, 2017). At a time when agriculture is becoming less important in the overall economy, the share of agriculture exports, expressed as a percentage of total GDP, rose from 1.6% in 1998 to 3.2% in 2015, driven mainly by growth in non-traditional agriculture exports (the World Bank, 2017). Peru's combination of business climate, trade preferences, low labor costs, and climatic conditions helped lay the foundation for developing a competitive and successful agricultural export industry (Meade *et al.*, 2010). In addition, the private sector has played a key role in agriculture export growth. The impressive growth in agricultural exports has been accompanied by rapid diversification of the product range and expansion of export destinations. In 2016, Peru exported 629 agricultural products to over 142 countries across the globe. The rapidly growing agriculture exports have attracted increased interest from domestic and international investors in the nation's agriculture sector (the World Bank, 2017).

Thus far, many studies have been conducted to investigate the nature and impact of relationships between agricultural exports and economic growth in developing countries across mainland Asia, Europe, and Africa. However, empirical investigation into agricultural export-led growth is lacking in the case of many Latin American nations – Peru in particular. Given the increased relevance of agriculture exports to the economic growth of Peru, the causal dynamics between the two is an empirical question worthy of further investigation. In this paper, we try to bridge this important gap in the empirical literature by using co-integration, Granger causality, and Vector Autoregression techniques to estimate the short- and long-run contribution of agriculture commodity exports to the economic growth of Peru. These techniques are sound because of their ability to estimate the short- and long-run situation and test for the direction of causality between variables. In addition, the multivariate framework of causal investigation used in this study has an edge over some bivariate models used previously in similar studies. In so doing, the paper is structured as follows. Section 2 provides a literature review, which is followed by a methodology and data section (Section 3). Section 4 demonstrates the results of our models together with their discussion, while the last part (Section 5) concludes.

Literature review

Theoretical underpinnings of exports have evolved from David Ricardo's comparative advantage in the early nineteenth century (Ricardo, 1817) to the new trade theories that emerged in the latter part of the twentieth century (e.g., Helpman and Krugman, 1985; Kunst and Marin, 1989). The classical economists, including Ricardo, have argued that international trade is the main source of economic growth and more economic gain is attained from specialization. Accordingly, welfare can be maximized if countries specialize in the production of those goods where they have a comparative advantage. The new trade theories have made progress in moving towards an understanding of inter-country differences in technological capabilities and providing a case to support government policy geared towards international competitiveness. The proponents of new trade theory assert that economies of scale will lead to cost reductions, and subsequently a bi-directional causality between export growth and economic growth (Helpman and Krugman, 1985). The theories and arguments of both classical and modern economists have contributed to the hypothesis of export-led economic growth in both developed and developing economies.

During the past few decades, the bulk of empirical research has been conducted to explore the effects of exports on economic growth (or, the export-led growth hypothesis). These studies, involving different countries, variables, and methodologies, and have come up with divergent conclusions. Some studies state that a bidirectional relationship exists between exports and economic growth; whereas the other studies state that a unidirectional relationship exists, supporting the fact that growth in exports results to economic growth. However, other studies have reported no evidence to support the export-led growth hypothesis. Rather than reporting individual studies, we highlight the divergent results. For instance, earlier studies by Chenery and Strout (1966); Kravis (1970); Balassa (1978); Tyler (1981); and Ram (1985) found positive and strong correlations between exports and economic growth, supporting the hypothesis that growth in exports has resulted in the economic growth of many developing economies. Similarly, many recent studies, such as those of Shahbaz and Mohammad (2014); el Alaoui (2015); Simon and Sheefeni (2016); and Bakari (2017), have also reported similar findings in the case of developing economies. Many of these studies have argued that the exports of goods and services generate foreign exchange that is required to import foreign goods by the developing economies. The increase in underlying commodities' imports, in turn, stimulates a nation's capacity to produce in the long run. Empirical evidence of export-led growth has also been confirmed in serval developed and industrialized economies such as Germany, Switzerland, Canada, United Kingdom and Japan (Kugler, 1991; Henriques and Sadorsky, 1996; Boltho, 1996). Cuaresma and Wörz (2005) argue that significant positive externalities accrue to the exporting country as a result of competition in international markets, including increasing returns to scale, learning spill-overs, increased innovation, and other efficiency gains, all of which can increase the rate of economic growth. Conversely, other studies have concluded that the positive relationship between exports and economic growth did not exist in some countries during certain periods (e.g., Helleiner, 1986; Ahmad and Kwan, 1991; Onafowora and Owoye, 1998; Faridi, 2012), leading the authors to refute the export-led growth hypothesis.

A vast majority of the studies mentioned above have reported possible causality between exports and economic growth. Just a casual review of the relationship between exports and GDP would lead one to infer that the correlation between the two is positive (Feder, 1983). However, these studies have not resolved, in sufficient detail, the causality between these two variables. Moreover, few studies have implicitly assumed that export growth causes output growth without formally testing the direction of causality. Another major issue surrounding the available literature is that the original time series data used, in many cases, is not co-integrated for any meaningful inference. A non-stationary time series data set has a different mean at different points in time and its variance increases with the sample size (Yifru, 2015). Yifru (2015) reports that non-stationary data, as a rule, are unpredictable and cannot be modelled or forecasted. In order to achieve consistent and reliable results, the non-stationary data needs to be transformed into stationary data. The Johansen procedure takes care of the above shortcomings by assuming that there are multiple co-integrating vectors. Pistoresi and Rinaldi (2010) investigated the relationship between real exports and real GDP in Italy from 1863 to 2004 by using co-integration analysis and causality tests. The results revealed that the variables co-moved in the long run but the direction of causality depended on the level of economic development. In recent years, the application of co-integration techniques and error correction models for the investigation of the export-led growth hypothesis have been proposed by several economists. Representative studies that apply these methods include those of Bokosi (2015); Simon and Sheefeni (2016); and Bakari (2017)

Although previous studies depict a positive relationship between total exports and economic growth, it is reasonable to question whether the same holds for all the primary exports. However, research into the relationship between primary exports such as agricultural exports and economic growth has not been given serious attention until recently. Some economists (e.g. Verter, 2015; Verter and Becvarova, 2014) argue that rising agricultural exports play a pivotal role in economic growth, particularly in developing economies. Despite its long-recognized role in development processes, empirical research on agricultural export-led economic growth has been, to some extent, left behind. Earlier studies in this direction include that of Johnston and Mellor (1961) who cite several important roles for agriculture in the development process. Some of the recent studies, including those of Dawson (2005); Aurangzeb (2006); Sanjuán-López and Dawson, (2010); Gilbert *et al.* (2013); and Hyunsoo (2015), support the export-led growth hypothesis for some agricultural commodities in developing countries. Conversely, the studies of Marshall *et al.* (1991) and Faridi (2012) found no evidence of export-led growth in the developing countries they investigated. Mucavele (2013) argues that, in general, agriculture's performance and its contribution to a nation's economic development has traditionally been undervalued because its linkages (forward and backward) with other sectors of the economy, including the value added by these linkages, do not appear in the basic statistics of many developing countries. Another major issue is that of "adding up" caused by low price elasticity of demand for agriculture commodities, which can result in lower export revenue as volume exported increases and the average price of the commodities decreases (Hallam *et al.*, 2004).

On the whole, it seems evident that many studies have investigated relationships between agricultural exports and economic growth in developing countries across mainland Asia, Europe, and Africa, though empirical investigation on the agricultural export-led growth is lacking in many Latin American nations and Peru in particular – the gap which aims to be filled by this paper

Methodology

This research was fundamentally analytical and descriptive as it embraced the use of secondary data to determine the effect of traditional and non-traditional agricultural exports on economic growth in Peru, in both the short- and the long run. For the analytical test, econometric modeling of the annual time series data was used. For the descriptive analysis, the description of the regression of the Solow model was used.

For the current research, we needed the annual time series data that covered the period between 2000-2016 including, data on Gross Domestic Product (GDP), data on the traditional agricultural exports, non-traditional agricultural exports, labor force and on the fixed capital formation value. The data for this research was obtained, as it was mentioned from secondary resources, especially from the Peruvian Central Bank of Reserve (PCBR), PCBR Annual Reports, from the National Bureau of Statistics, from the Ministry of Labor in Peru and from the World Bank Indicators.

In order to examine the contribution of traditional and non-traditional agricultural exports to economic growth (a supply-side perspective), it is necessary to consider the neoclassical growth model developed by Solow (1956), which includes the capital and the labor force as main variables of the production function. The model is specified by the following equation:

$$Y_t = f(L_t, K_t) \qquad (1)$$

In order to fulfil the main objective, that is, to describe how agricultural exports affect economic growth, it is necessary to incorporate both traditional and non-traditional agricultural exports in equation (1).

$$Y_t = f(L_t, K_t, Y_t, ATX_t, ANTX_t) \qquad (2)$$

To discard the differences in the measurement units, we applied the natural logarithm on both sides of the equation 2 as follows:

$$LGDP_t = \beta_0 + \beta_1 LATX_t + \beta_2 LANTX_t + \\ + \beta_3 LFKF_t + \beta_4 LLF_t + \beta_5 LGDP(\text{-}1) + e_t \qquad (3)$$

where:
LGDP = Natural logarithm of the Gross Domestic Product in million dollars.
LATX = Natural logarithm of traditional agricultural exports in million dollars.
LANTX = Natural logarithm of non- traditional agricultural exports in million dollars.
LFKF = Natural logarithm of fixed capital formation in million dollars.
LLF = Natural logarithm of labor force.
LGDP(-1) = Natural logarithm of one year lagged Gross Domestic Product.
e_t = Error term.
β_0 = Constant term.
$\beta_1 - \beta_5$ = Parameters of explanatory variables estimated in the model.

Estimation procedures

For the short run analysis, we used the Vector Autoregression (VAR) Model, enforced for the Unit Root Test and the Causality Test; and for the long run analysis, we used the Co-integration Test.

Unit root test

A variable is considered as stationary if it has a constant mean, variance and autocovariance at any measured point. A non-stationary time series may become stationary after differencing a number of times. If the series is not stationary at the base level, it will be stationary after successive differencing. The order of integration of a series is the number of times it needs to be differenced to become stationary. A series integrated of order I (n) becomes stationary after differencing n times. In this study the stationary test was carried out using the Augmented Dickey-Fuller (ADF) test, which was formulated by Dickey and Fuller (1979, 1981). The decision rule states the series is stationary if the ADF test statistic is greater than the critical value, while it is not stationary if the test statistic is less than the critical value. The general ADF Test form is represented by the following regression:

$$\Delta Y_t = \alpha_0 + \alpha_1 \cdot Yt_{-1} + \Sigma\alpha \cdot \Delta Y_t + e_t; \quad (4)$$
it includes only the drift

$$\Delta Y_t = \alpha_0 + \alpha_1 \cdot Yt_{-1} + \Sigma\alpha \cdot \Delta Y_t + \delta_t + e_t; \quad (5)$$
it includes the drift and linear time trend

where:
Y = time series of specified variable
t = time trend
Δ = first differencing operator $\Delta Y_{t-1} = Y_t - Y_{t-1}$
α_0 = constant term
N = optimum lags' number
e_t = random error term

Johansen co-integration test

The test was developed in 1989-1990 by Johansen and Juselius (Johansen, 1991) is necessary to determine the existence of a long run equilibrium (stationary) relationship between the dependent and the explanatory variables. The co-integration of two (or more) time series suggests that, there is a long run or equilibrium relationship between them. It determines the number of co-integrated vectors in a model that is based on the method of two likelihood ratio test statistic; the Maximal Eigenvalue Test and the Trace Statistic Test. The null hypothesis is the non-existence of co-integration between the variables, which will be rejected when the test statistic is greater than the critical value, indicating that there exists a co-integration in the long run.

Pairwise Granger causality test

To examine the significant causality relationship of agricultural exports, fixed capital formation and the labor force with economic growth in Peru, we performed a Granger Causality Test (Granger, 1969). The independent variable is considered as a Granger-cause variable of Y, if the y_t (the variable Y in the current period) is conditional on the past values of the variable X ($x_{t-1}, x_{t-2}, x_{t-1} \ldots x_0$).

Focusing on the total traditional agricultural exports, the total non-traditional agricultural exports, the fixed capital formation and the labor force as the engines of the economic growth, we are interested in the bidirectional causal relation between them to provide evidence of those independent variables as causes of the economic growth between 2000 and 2016. Therefore, we considered the following hypotheses:

For the case of *LGDP* (Logarithm Gross Domestic Product) and *LATX* (Logarithm of traditional agricultural exports):

i. *LATX* does not Granger Cause *LGDP*
ii. *LGDP* does not Granger Cause *LATX*

For the case of *LGDP* (Logarithm Gross Domestic Product) and the *LANTX* (Logarithm of non-traditional agricultural exports):

i. *LANTX* does not Granger Cause *LGDP*
ii. *LGDP* does not Granger Cause *LANTX*

For the case of *LGDP* (Logarithm Gross Domestic Product) and the *LFKF* (Logarithm of Fixed Capital Formation):

i. *LFKF* does not Granger Cause *LGDP*
ii. *LGDP* does not Granger Cause *LFKF*

For the case of *LGDP* (Logarithm Gross Domestic Product) and the *LLF* (Logarithm of Labor Force):

i. *LLF* does not Granger Cause *LGDP*
ii. *LGDP* does not Granger Cause *LLF*

Vector Autoregression (VAR) Model

The Vector Autoregression is frequently used for analyzing the dynamic impact of random disturbances on the system of variables. The VAR Model approach treats each endogenous variable in the system as a function of lagged values of all endogenous variables in the system. This model is also a dynamic system of equations, which examines the impacts of interactions between economic variables. The model is represented by the following:

$$Y_t = \alpha + \Sigma\alpha_i \cdot \Delta Y_{t-1} + e_t \quad (6)$$

When this equation is extended, the model will be:

$$Y_t = \alpha + \alpha_1 \cdot Y_{t-1} + \alpha_2 \cdot Y_{t-2} + \alpha_3 \cdot Y_{t-3} + \ldots + \alpha_k \cdot Y_{t-k} + e_t \quad (7)$$

where:
Y_t = vector of endogenous variables at time t
$\alpha_{i\ (i = 1, 2, \ldots, k)}$ = (n x n) coefficient matrices that describe the relationship between endogenous and exogenous variables
e_t = vector of residuals or random disturbances

The above equation will change with the inclusion of the lag operator (L):

$$Y_t = \alpha \cdot (L) \cdot Y_{t-1} + e_t \quad (8)$$

where:
Y_t = vector of endogenous variables at time t
$\alpha_{i\ (i = 1, 2, \ldots, k)}$ = (n x n) coefficient matrices that describe the relationship between endogenous and exogenous variables
$\alpha \cdot (L)$ = matrix of coefficients.
e_t = vector of residuals or random disturbances

Results and discussion

Before the comprehensive econometric analysis, a brief interpretation of statistical analysis is necessary. The definitions and summary of the statistics of those variables are provided in Table 1, which reported that the average of the GDP growth was US$ 122,819.20 million with US$ 58,684.71 as the standard deviation. In the case of the traditional agricultural exports, the average was US$ 639.96 million and the standard deviation was US$ 392.92. For the case of non-traditional agricultural exports, it had an average value of US$ 2,066.84 million and a deviation standard of US$ 1,458.64. It also showed that the fixed capital formation had a mean value of US$ 27,203.35 and a deviation standard of US$ 15,932.23. Finally, the labor force had a mean value of 15.19 and a deviation standard of 1.92.

As regards skewness, the GDP and the FKF presented an approximately symmetric distribution, while the ATX, the ANTX and the LF showed a moderately skewed distribution.

The Augmented Dickey-Fuller test was also used, performed on all variables (gross domestic product, traditional agricultural exports, non-traditional agricultural exports, fixed capital formation and labor force). The results of Augmented Dickey-Fuller test for showing the existence of unit root of once differenced data have been represented in Table 2.

The reported result in Table 2 confirmed the stationary test of the variables at the level form I (0) for the LGDP, LANTX and for the LLF. In the case of LATX and LFKF, those variables showed stationary at the level form I (1). According to this, the null hypothesis of non-stationary could be rejected at 5% and 10% critical value level, confirming that the ADF test statistics were greater than the critical value, which also could be understood as the P-value was significant at the level form I (0) because it is less than 0.05. Since the null hypothesis was rejected for all the variables at a convenient significant level, the variables did not have a unit root at levels. Therefore, we can conclude that the variables data were stationary at the level of order one I (1). Those stationary tests supported the econometric model of the equation (6).

Table 3 presents the result of the Johansen Co-integration Test in the Trace Statistic and in the Maximum Eigen Test statistics. Both test statistics revealed that there were four co-integrating equations. This was because at the null hypothesis of co-integration rank (r=0) the max-eigenvalue of 48.0754 was greater than the 5% critical value of 33.46. The trace statistics also indicated 4 co-integrating equation since trace value of 112.784 was greater than the 5% critical value of 68.52. The evidence of co-integration in the study indicated that traditional agricultural exports, non-traditional agricultural exports, fixed capital formation and labor force are long-run determinants of economic growth in Peru. The result of the Johansen statistics, therefore, rejects the null hypothesis of no co-integration among the variables.

The same long-run relationship between agricultural exports, gross fixed capital formation and economic growth was found in the study made by Gbaiye *et al.* (2013), in Nigeria; and confirmed by Ijirshar (2015); by Ouma *et al.* (2016), in Kenya, Uganda and Rwanda; by Fakhre and Godwin (2016), in Tanzania and by Simasiku and Sheefeni (2017), in Namibia.

As to Granger causality, the following relationships were analysed: the causal relationship between the LATX (Logarithm of traditional agricultural exports) and the LGDP (Logarithm Gross Domestic Product); the causal relationship between the LANTX (Logarithm of non-traditional agricultural exports) and the LGDP (Logarithm Gross Domestic Product); the causal relationship between the LFKF (Logarithm of Fixed Capital Formation) and the LGDP (Logarithm Gross Domestic Product); and the causal relationship between the LLF (Logarithm of Labor Force) and the LGDP (Logarithm Gross Domestic Product). Table 4 shows that value of the Granger Causality Test, considering the probability value of 5%.

The result for the causal relationship between LATX (Logarithm of agricultural exports) and the LGDP (Logarithm Gross Domestic Product) showed it was unidirectional, while the LATX didn't have an influence on the LGDP, though the LGDP had an influence on the LATX. According to Abrar ul Haq (2015), in a study made in Pakistan, the reason of this result was because the exportation of those products were in a raw material more than value-added product, and a higher gross domestic product increased the investment in the sector as in other sectors. The same result was made for Ouma *et al.* (2016) in Uganda, Tanzania and Burundi.

For the case of the LANTX (Logarithm of non-traditional agricultural exports) and the LGDP (Logarithm Gross Domestic Product), it was demonstrated that there was also a unidirectional causal relationship between them, where the non-traditional agricultural exports Granger caused the gross domestic product. The same result was presented for

Table 1: Summary statistics of variables, 2000-2016.

Variable	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis
GDP	122,819	120,550	201,217	51,744	58,684	0.14	1.42
ATX	640	634	1,689	207	393	1.00	3.94
ANTX	2,067	1,828	4,667	394	1,459	0.52	1.92
FKF	27,203	26,749	50,899	9,165	15,932	0.21	1.45
LF	15	16	18	12	2	-0.50	1.96

Source: researcher's compilation from Stata 13.0

Table 2: Unit root test for order of integration of variables (ADF).

Variables			Critical values 5%	Result
LGDP	At level	-2.078	-1.812	Stationary
	First difference	-1.865	-1.860	Stationary
LATX	At level	-1.655	-1.812	Non-stationary
	First difference	-1.870	-1.860	Stationary
LANTX	At level	-2.260	-1.782	Stationary
	First difference	-2.445	-1.812	Stationary
LFKF	At level	-1.487	-1.782	Non-stationary
	First difference	-2.349	-1.812	Stationary
LLF	At level	-8.807	-1.761	Stationary
	First difference	-3.393	-1.782	Stationary

Source: researcher's compilation from Stata 13.0

Table 3: Johansen Cointegration Trace and Maximum Eigvenvalue Test results.

Hypothesized No. of CE(S)	Trace Test		Maximum Eigen Test	
	Max-Eigen Statistic	0.05 Critical Value	Trace Statistic	0.05 Critical Value
None	48.075	33.460	112.784	68.520
At most 1	29.328	27.070	64.709	47.210
At most 2	19.150	20.970	35.381	29.680
At most 3	14.225	14.070	16.231	15.410
At most 4	2.007*	3.760	2.007*	3.760

* Shows that it has a value significance at 5%.
Source: researcher's compilation from Stata 13.0

Odetola and Etumnu (2013) in a study in Nigeria. The same result was made for Bulagi *et al.* (2014) in South Africa, for Fakhre and Godwin (2016) in Tanzanian, and for Ouma *et al.* (2016) in Rwanda.

This analysis also showed that the Gross Domestic Product Granger caused the Fixed Capital Formation, but this variable didn't have any influence on the gross domestic product. It is analyzed in Malaysia for Albiman and Suleiman (2016), who demonstrated that the economic growth Granger caused the domestic investment and not otherwise.

Finally, about the causal relationship between the LLF (Logarithm of Labor Force) and the LGDP (Logarithm Gross Domestic Product), there exists a unidirectional causal relationship between those variables. The labor force Granger caused the gross domestic product, but it didn't have any influence in the labor force.

Going further, Table 5 presents the result of the Vector Autoregression Model, which reveals the relationship between the dependent and independent variables in a short long term.

The result of the regression equation (3) is shown in Table 5. It indicates that this function best fit the model with significant effects on the GDP, having 99.85% as the R2. This result implied that independent variables explained 99.9 % of the total variation in the GDP in the short long run. The Probability of F-statistic was 0.0000 that indicated the significance, which implied that the parameters were significant at 5% even at 1%. The Breusch-Godfrey Correlation LM Test was used to test the existence or not of autocorrelation, having as a null hypothesis the no autocorrelation against the alternative hypothesis of autocorrelation. In this particular case, the value was 0.4822 that implied the no rejection of the null hypothesis. So, the estimated model is free from autocorrelation.

For the case of testing the existence of residuals normality, the Jarque-Bera test was used. It had as a null hypothesis that the residuals are normally distributed against the alternative hypothesis, which was the residuals are not normally distributed. In this case, the result was 0.3037, which implied the no rejection of the null hypothesis and it showed the normal distribution of the residuals.

According to this result, there was a partial elasticity of the Traditional Agricultural Exports (LATX), which had a value of 0.06. This meant an increase of 1% in the Traditional Agricultural Exports would result in 0.06% increase in the Gross Domestic Product (LGDP). In addition, this result had a significance at 10%. This result was also showed in other studies made in Kenya by Ouma *et al.* (2016), in 34 developing countries by Mehrara and Baghbanpour (2016) and in Namibia by Simasiku and Sheefeni (2017). Those showed that the agricultural exports had a positive but low impact in the GDP. In those studies, the significance of the result was explained by the production techniques of individual families with low income, who produced in small scale and sold the products in a raw state.

The coefficient of the Non-Traditional Agricultural Exports (LANTX) was also significant at 10% in the short-run. An increase of 1% in the Non-Traditional Agricultural Exports (LANTX) resulted in an increase in the economic growth (LGDP) by 0.14%. This result was compatible with other studies of Sanjuán-López and Dawson (2010) and of Simasiku and Sheefeni (2017), who explained the result of the high statistical significance was related to the value of added products and the high prices relation in the world market.

About the control variables such as the Fixed Capital Formation (LFKF), it had a positive and insignificant impact on the economic growth in Peru at significance level of 1%. The result implied that an increase of 1% in fixed capital formation should produce an increase of 0.36% in gross domestic product (LGDP). According to Noula *et al.* (2013) for Cameroon, to Kanu and Ozurumba (2014) for Nigeria, to Albiman and Suleiman (2016) for Malaysia, to Bakari (2017) for Gabon and to Simasiku and Sheefeni (2017) for Namibia, in the short run, the positive impact on the increase of domestic investment had to support the economic growth more.

In the case of the Labor Force (LLF), it had a positive, but insignificant impact on the economic growth of Peru. When there was an increase of 1% in the labor force, it produced an increase of 0.31% in the gross domestic product (LGDP). The same relationship was found in Cameroon by Noula (2013) and in Ethiopia by Yifru (2015). In addition, in common with that study result, the labor force was reported as making a greater contribution to economic growth as compared with fixed capital formation. This situation can be explained in terms of much of the population having agriculture production as their principal labor, which is converted gradually into human capital, which is considered to be the primary source of the country's economic growth.

Table 4: Pairwise Granger causality test results.

Null hypothesis	F-statistic	Prob.
LATX does not Granger Cause LGDP	0.005	0.945
LGDP does not Granger Cause LATV	5.503	0.028
LANTX does not Granger Cause LGDP	4.246	0.046
LGDP does not Granger Cause LANTX	0.934	0.425
LFKF does not Granger Cause LGDP	3.336	0.091
LGDP does not Granger Cause LLFKF	4.673	0.049
LLF does not Granger Cause LGDP	14.183	0.002
LGDP does not Granger Cause LLF	0.003	0.956

Source: researcher's compilation from Stata 13.0

Table 5: Short-run dynamic of factors that affect the economic growth.

Variable	Coefficient	Std. Error	t-Statistic	P-value
D(LATX)	0.056	0.032	1.790	0.100*
D(LANTX)	0.136	0.086	1.580	0.100*
D(LFKF)	0.359	0.082	4.370	0.000***
D(LLF)	0.311	0.481	0.650	0.500
D(LGDP-1)	0.189	0.115	1.640	0.100*
Constant	3.626	1.090	3.330	0.000***
R-squared	0.999			
Prob (F-statistics)	0.000			
Breusch-Godfrey LM Test	0.482			
Jarque-Bera (Prob)	0.304			

Note: *,*** mean significance at 10% and 1%, respectively.
Source: researcher's compilation from Stata 13.0

Finally, where the lagged GDP is concerned, it had a positive impact on economic growth in Peru and it is significant at 10%. When the lagged GDP increased by 1%, it implied an increase of 0.12% of the economic growth (LGDP). This result was according to the multiplier-accelerator interaction, which implied that the previous period GDP increased the investment level of the country that led to increase the GDP in the current period.

We are aware that our study has a number of limitations. First of all, the study assessed the contribution and impact of agricultural exports on economic growth in Peru by using yearly agricultural exports data from 2000-2016. It did not cover earlier periods because of the absence of a complete data set. The study used only officially available data and did not regard any unofficial flows of agricultural products to other countries. Furthermore, our analysis was limited to the volume of total agricultural exports and did not examine their competitiveness on the international market. Moreover, issues concerning the impact of non-agricultural exports on economic growth were not discussed. Future research should address these limitations to come up with a more reliable estimations of the impact of agricultural exports on the economic growth of Peru. More importantly, to evaluate the true contributions' of agriculture exports to the economic growth, future research should take into account the externalities and its forward and backward linkages with service, manufacturing and the trade sector.

Conclusion and policy implications

Agriculture is fundamental to Peru's socioeconomic development and has remained an important source of foreign exchange earnings. Despite its substantial contribution to the total exports during the last few decades, it is astonishing that there has rarely been an empirical study on the impact of agricultural exports to the national economy. Therefore, the overarching goal was to investigate the contribution and impact of agricultural exports – both traditional and non-traditional – on the economic growth of Peru in the short and the long run. The empirical analysis was done on the basis of annual time series data from the period 2000-2016, applying Vector Autoregression modeling and various estimation procedures such as ADF test, Co-integration test, and Granger Causality test.

The ADF Test used to determine the stationarity of the data showed that with the exception of traditional agricultural exports and fixed capital formation, all variables achieved stationary at level I (0) implying the regression model used for the short run analysis avoided spurious results. In the case of the short run analysis, the results revealed a positive relationship between the traditional agricultural exports and the economic growth; and between the non-traditional agricultural exports and the economic growth. It also showed that the significance of non-traditional agricultural exports was stronger than that of traditional agricultural exports on the economic growth of Peru in the short-run. Likewise, the Co-integration test result revealed a long-run relationship between the traditional agricultural exports, non-traditional exports and economic growth of Peru. Finally, the Granger Causality test revealed a unidirectional causality relationship between both traditional and non-traditional agricultural exports and the GDP. However, in the first case, the GDP Granger caused the traditional agricultural exports while in the second case, it was the non-traditional agricultural products that Granger caused the GDP. These results are far from surprising as the last decade witnessed a steady decline in the dollar values of many of the traditional agricultural export crops, highlighting the risks of depending upon traditional agricultural exports as a source of foreign exchange earnings. Unlike the traditional agricultural exports, the volume and the price of many non-traditional agricultural exports grew steadily during the last decade resulting in a much stronger positive correlation of non-traditional agricultural exports with economic growth of Peru. As concerns our explanatory variables, the results showed that the labor positively contributed to economic growth, which can be explained by the transformation of the labor force through quality education and skill-based training. We also found that fixed capital formation contributed positively to the GDP, which was expected a priori.

The insights from the study lends general support to the agriculture export-led growth hypothesis for Peru. In particular, there is a strong empirical evidence of a positive relationship between non-traditional agricultural exports and economic growth at the macroeconomic level in both short-run and long-run. As export earnings from traditional agricultural products has stalled, much attention is needed in the non-traditional agricultural sector. However, some challenges still persist. In particular, improving productivity throughout agriculture sector and diversifying economic activities towards higher value-added production and exports are two major challenges for the medium- to long-term sustainability of Peru's growth and development. Institutional development such as phytosanitary controls, significant competition in regional markets, insufficient export infrastructure, and the great distance between Peru and its major trading partners create additional challenges. While the agriculture export of the country has seen notable growth and diversification in recent years due to enforcement of public policies that support innovation and technology transfer in the sector, to make better use of this source of growth requires continued institutional and policy reforms. In the light of the findings and the challenges, our study has the following policy implications:

- The agriculture sector should be prioritized in terms of increased budget allocation which will in turn raise agricultural GDP and promote export diversification.
- Since the non-traditional agricultural commodities such as avocado and grapes exhibit high-income elasticities, the production and export of non-traditional agricultural commodities needs to be prioritized over the traditional ones.
- In the case of traditional agricultural commodities, government should emphasize adding value rather than exporting the raw commodity since their price elasticity of demand is low. Farmers should also be trained in the mechanisms of adding value to their products before they go to the market.

- To encourage smallholders to actively engage in agriculture production and minimize the associated risks, government should provide schemes such as crop insurance, technical assistance on pest control and improve the access to credit.
- Government should incentivize all producers through grants, subsidies, tax breaks, and low rates of corporation tax.
- Good standards of education are essential to ensure that the workforce is of a sufficiently high caliber to deliver products of the standard and quality required by destination buyers. Labor laws must also meet international standards and expectations.
- The government should improve the marketing of agricultural products continuously, not only by promoting these products in the international market, but also in the internal market to cover the existing and growing local demand.
- While Peru's performance ranks high overall within the region, Peru lags far behind in the technological sphere as compared to several industrialized nations. Therefore, there is a need for technology diffusion from the more technologically advanced countries to improve productivity in the agriculture sector.
- Many of the successful smallholder schemes, in a wide range of traditional and non-traditional commodities, have been initiated and led by the private sector of the country. Therefore, more financial assistance should be provided by governments and/or donor agencies to support those initiatives, such as revolving credit funds, extension advice, training, and building of cold stores which are currently financed by the private sector.
- The government should play a more proactive role in fostering innovation to develop new competitive advantages, overcome bottlenecks and alleviate constraints that hinder the growth of agriculture exports.

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Implicit Cost of the 2010 Foot-and-Mouth Disease in Korea

The most destructive foot-and-mouth disease (FMD) outbreak in Korea occurred in November 2010. Various studies have quantified the economic impact of culling affected animals, mostly swine, from the event by applying different assumptions to the Input-Output (IO) model. The present study takes into account a type of implicit cost, considering the types of effects in the previous literature, as well as costs that have been unaccounted for in prior studies. A seasonal autoregressive model (SARIMA) is estimated employing the number of swine slaughtered leading up to the 2010 FMD outbreak, and forecasts from the model are compared to the actual drop and rebound. The unaccounted implicit cost is estimated to be more than 2 trillion Korean Won (≈ 1.8 billion US dollars), which is a cost Korea must give up or cannot recover. This study serves to strengthen the justification of applying preventive efforts to reduce the likelihood and economic impact of an animal disease outbreak and may be applied in other countries.

Keywords: Foot-and-Mouth Disease (FMD), Implicit cost, Seasonal autoregressive integrated moving average (SARIMA)

JEL classifications: Q11; Q13; R15

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Introduction

Foot-and-Mouth Disease (FMD) is a highly contagious viral disease that affects cloven-hoofed animals such as cattle and swine. Animals with FMD typically have a high fever and blisters on the mouth, the mammary glands, and around the hooves (USDA APHIS, 2013). Affected animals will not die from FMD, but animals will be weakened and unable to produce meat and milk as before (USDA APHIS, 2013). FMD is transmitted directly through animal movement or indirectly through non-animal fomites or airborne transmission. An outbreak of FMD usually results in culling or killing affected animals ("stamping out") and thus causes substantial economic losses in livestock sectors and related industries, such as the dairy and meat processing sectors.

Numerous research has addressed matters related with FMD outbreaks. Certain studies have evaluated different strategies to control the outbreak of an FMD incidence. Garner and Lack (1995) investigated alternative control plans in Australia, using epidemiological simulation with an Input-Output (IO) model (explained in detail below). They determined that destroying infected animals reduced the duration of the outbreak. Ekboir (1999) utilized similar IO modelling approaches and assessed the impact of a FMD outbreak in California (U.S.). Ekboir (1999) found that vaccination is the least expensive control strategy and that immediate migration is vital to stemming an outbreak. Schoenbaum and Disney (2003) determined that effective control(s) of an FMD outbreak depend on herd demographics and regional contact rates. Other studies such as Zhao *et al.* (2006), Jones (2010), and Kim *et al.* (2017) found that an improved animal traceability system may help to reduce the negative economic consequences of an FMD outbreak.

A different vein of research involves quantifying the economic impacts of an FMD outbreak. These studies used an IO model to measure the economic impacts of a hypothetical or simulated FMD outbreak. Lee *et al.* (2012) estimated the economic impacts of a hypothetical agroterrorism attack that made use of FMD pathogens. Pendell *et al.* (2007) also investigated a hypothetical impact of an FMD outbreak on the economy of southwest Kansas by using the Social Accounting Matrix approach, which is an extended IO model. Previously, Caskie *et al.* (1999) had used an IO model to quantify the economic effects of a BSE-induced reduction of livestock for Northern Ireland. More recently, Schroeder *et al.* (2015) also utilized the IO framework for evaluating the effect of a high-capacity emergency vaccination during an FMD outbreak.

Studies that measure the effects from an actual FMD outbreak include Scudamore (2002) and Thompson *et al.* (2002) for a case in the United Kingdom (UK). In 2001, the UK experienced a severe FMD outbreak. At least 57 premises were infected by the time the first case was identified in February of that year (Scudamore, 2002). By September 2001, over 6 million animals had been killed and the disease had spread to Ireland, France and the Netherlands (Scudamore, 2002). Thompson *et al.* (2002) estimated economic losses from the FMD incidence in the UK to be between 10.7 billion US dollars to 11.7 billion US dollars. The 2010-2011 FMD outbreaks in Korea were severe and caused large economic effects on livestock sectors and related industries in Korea. The number of culled animals were upwards of 3.5 million heads from November 2010 to April 2011. More than 90% of the culled animals were swine (3.3 million heads) (KREI, 2011, Table 3-18, pp. 147-148). Using the IO model, KREI (2011) estimated the economic impact due to FMD outbreak in 2010 to be more than 4 trillion Korean Won (≈ 3.6 billion US dollars) (KREI, 2011, p. 283).

The economic impacts from animal disease like FMD can be divided into three categories. First, the "direct impacts" are from the reduction in animal production due to culling/killing animals. Second, the "indirect impacts" are from changes in inter-industry transactions as they respond to the affected livestock industry; for example, losses in dairy and meat processing sectors; and third, the "induced effects" which are the decreases in household income generated from the direct and indirect effects.[1] Input-Output (IO) analysis measures these impacts using IO multipliers (Miller and Blair, 2009). Moon *et al.* (2013b) analysed the multiplier effects of FMD outbreaks in 2000, 2002, and 2010 using the Korean IO model. They estimated the total economic impact of FMD outbreak in Korea in 2010 to be 3.5 trillion Korean Won (≈ 3.2 billion US dollars). KREI (2011) also estimated the economic impact due to FMD outbreak in 2010 to be more than 4 trillion Korean Won (≈ 3.6 billion US dollars) using a similar approach. KREI (2011) and Moon *et al.* (2013b) estimated the economic impacts from FMD outbreak using a standard demand-driven IO model in situations where the FMD outbreak alters the final demand. Kim (2015) suggested a supply-driven IO approach because the FMD outbreak alters livestock production, i.e., supply, not the final demand. Kim (2015) estimated these economic impacts to be 7.6 trillion Korean Won (≈ 6.8 billion US dollars) which is substantially higher than the other two studies.

As Pendell *et al.* (2007) and Kim (2015) pointed out, the FMD outbreak in the UK confirmed the need to investigate and understand the economic impacts of these FMD events, in order to develop effective public policies that abate the effects from these outbreaks. In the case of Korea, KREI (2011), Moon *et al.* (2013b), and Kim (2015) reported the economic impacts of the 2010 FMD outbreak in Korea using the IO framework as well. Preventive controls of the animal disease outbreaks are important to help mitigate economic losses from such outbreaks. As discussed in previous studies, an animal disease like FMD may cause severe economic impacts. Moreover, as food supply chains have become increasingly global, the impact on international trade of a potential FMD outbreak has grown to be a major concern for livestock exporters (Park *et al.* 2008). Export countries have a vital interest in maintaining FMD-free status to maintain trade relationships.

Where preventive controls of animal disease outbreaks are concerned, African Swine Fever (ASF) should receive close attention, especially in Europe given its geographic proximity. ASF is an endemic and highly contagious haemorrhagic disease of swine (Beltrán-Alcrudo *et al.* 2017). ASF is currently widespread in sub-Saharan Africa, Eastern Europe and the Italian island of Sardinia. With the increased transmission of ASF, there is growing global concern that the virus may spread further into other regions (Beltrán-Alcrudo *et al.* 2017). Since 2015-2016, ASF has maintained its presence and continues to spread throughout Russia, the Ukraine, Estonia, Latvia, Lithuaia and eastern Poland (USDA FAS, 2016). As such, the present investigation offers pertinent inferences for the European region. As emphasized in this study, the economic costs of the outbreak may actually be higher when the unaccounted cost is taken into consideration.

This research begins with a question regarding the implicit costs of "actual" livestock diseases like the 2001 FMD event in the UK and 2010 FMD event in Korea. In particular, we study the more recent 2010 FMD outbreak in Korea and its effect on the country's main livestock industry – swine. This outbreak led the the United Nations Food and Agriculture Organization (FAO) to issue a call for increased global surveillance. Our approach is also applicable to measuring the effects from other actual or hypothetical major disease outbreaks. We use the term implicit cost in this paper to refer to the unaccounted economic cost, i.e., type of opportunity cost. Perhaps the term persistent costs would make better sense since the impact of the 2010 FMD outbreak was persistent for several months after the FMD had been contained. As described previously, explicit costs are the economic costs taken into account as a result of the damage from the FMD incident. These accounted costs are from the direct, indirect, and induced effects of culling the animals in response to the FMD outbreak. Conversely, the implicit cost or persistent cost is an unaccounted cost which can be estimated by comparing the level of livestock slaughtered under FMD outbreak (i.e., "the treatment group") to the number of livestock slaughtered *without* FMD outbreak (i.e., "a control group" or counterfactual scenario with no FMD). In doing so we estimate a cost equal to what we must give up (i.e. cannot recover) as a consequence of the FMD outbreak, which also includes unaccounted indirect and induced costs. We can estimate implicit indirect and induced costs using Input-Output framework as well.

Unfortunately, it is impossible to find a valid control or counterfactual situation because the FMD outbreak in 2010 occurred everywhere in Korea. Given the difficulties associated with obtaining a valid control group, time series methods are applied, specifically a seasonal autoregressive-moving average (SARIMA) model is used to estimate the counterfactual number of livestock slaughtered. Focusing on the swine sector in Korea, we find that between March 2011 and October 2011, the accumulative difference in the number of swine slaughtered was estimated to be a bit more than 2 million heads. The approximated implicit or unaccounted direct implicit cost of FMD is 1.06 trillion Korean Won (≈ 0.95 billion US dollars) assuming the average swine price received by farmers in 2011 to be 328,000 Won/110kg (≈ 295 US dollars/110kg). The implicit or unaccounted indirect and induced costs from this are also estimated to be 1.41 trillion Korean Won (≈ 1.27 billion US dollars) and 0.66 trillion Korean Won (≈ 0.59 billion US dollars), respectively; by using the standard IO multipliers from Bank of Korea (2014). Thus, the total implicit cost is estimated to be 3.14 trillion Won (≈ 2.83 billion US dollars), which is the cost Korea must give up due to the persistent FMD outbreak.

This paper contributes to the literature on estimating the effects of livestock disease in a regional economy, where up to date there is no study addressing the implicit cost of livestock disease outbreak. Thus, we seek to identify unaccounted economic effects of a major disease outbreak affecting a significant agricultural sector, by applying a different approach that permits to estimate and determine these (additional) omitted costs. This new study serves to strengthen the justification of applying preventive efforts to reduce the likelihood and the economic impact of an animal disease outbreak. The swine sector in Korea is studied in order to estimate the implicit cost of the FMD outbreak in 2010. This paper consists of four sections. Section 2 explains the data used and provides explanations of the method. Section

[1] We may add derived costs such as governmental expenditure/subsidies and environmental degradation from the carcass burial construction. Kim and Kim (2013) estimated the cost of environmental degradation from the carcass burial and sites construction.

3 contains the empirical results and policy implications and section 4 has remarks and concludes the paper.

Data and methodology

The number of swine slaughtered is taken from the Record of Livestock Slaughter, Animal and Plant Quarantine Agency, which are archived by the Korean Ministry of Agriculture, Food and Rural Affairs (each year). We compiled monthly data from January 2004 to December 2013 (132 observations). The data series is plotted in Figure 1. The number of swine slaughtered substantially decreased immediately following the FMD outbreak (November 2010 as indicated by the first grey vertical line in Figure 1) due to culling affected swine. The actual reduction in the number of swine slaughtered between the fourth quarter of 2010 (sum of number of swine slaughtered between October 2010 and December 2010) and the first quarter of 2011 (sum of number of swine slaughtered between January 2011 and March 2011) was 1.24 million heads. The number of swine slaughtered has steadily rebounded after the FMD outbreak. It seems to reach the level prior to the FMD in October 2012 (the second grey vertical line in Figure 1).

The autoregressive-moving average (ARMA) models use lags and shifts in the data to uncover patterns and predict the future values. Box and Jenkins (1976) discussed the general ARMA models. The autoregressive (AR) part of the model involves regressing the variable on its own lagged values and the moving average (MA) part involves modelling the error term as a linear combination of current and past error terms. Note that most of discussions regarding ARMA modelling in this article follows Lütkepohl and Krätzig (2004) closely including notations.

The model is referred to as *ARMA*(p,q) where p is the order of the AR part and q is the order of MA part as in equation (1)[2]:

$$y_t = \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \qquad (1)$$

where y_t is a stationary time series data and ε_t is the error term which is distributed independent identically, i.e., $\varepsilon_t \sim$ iid $(0, \sigma^2)$. Using the lag operators, where $L^k y_t = y_{t-k}$, equation (1) can be rewritten as

$$\phi(L)y_t = \theta(L)\varepsilon_t \qquad (2)$$

where here $\phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p$ and $\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_q L^q$.

The (non-seasonal) ARIMA models are extensions of the ARMA model, where here y_t is nonstationary (integrated), and where an initial differencing step is applied to convert the data into being stationary. Non-seasonal ARIMA models are denoted *ARIMA*(p,d,q) where parameter d is the degree of differencing[3]:

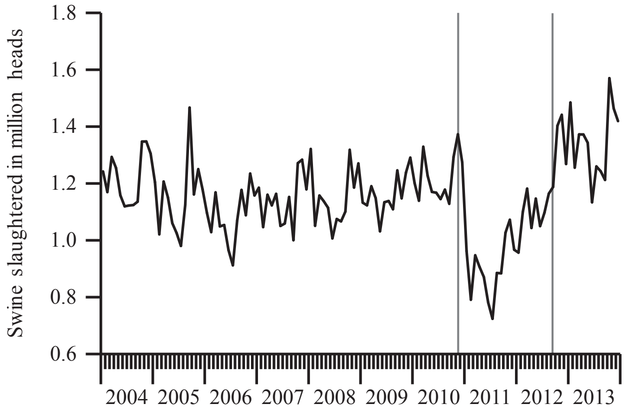

Figure 1. Monthly number of swine slaughtered and 2010 FMD outbreak.

Note: First grey vertical line – FMD outbreak (November 2010); second grey vertical line – the number of swine slaughtered seems to reach the level prior to FMD outbreak. Source: Animal and Plant Quarantine Agency, Korean Ministry of Agriculture, Food, and Rural Affairs.

$$\phi(L)\, \Delta^d y_t = \theta(L)\, \varepsilon_t \qquad (3)$$

The seasonal ARIMA (SARIMA) models are formed by including additional seasonal terms (e.g. $s = 12$ for monthly data) and is denoted by *SARIMA*(p,d,q)(P,D,Q)$_s$, where s refers to the number of periods in each season and the upper case P, D, and Q refers to the autoregressive, differencing, and moving average terms for the seasonal part of the ARIMA model[4]:

$$\phi_s(L^s)\phi(L)\Delta_s^d \Delta^d y_t = \theta_s(L^s)\theta(L)\varepsilon_t \qquad (4)$$

where $\phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p$; $\phi_s(L^s) = 1 - \phi_{s1} L^s - \cdots - \phi_{sP} L^{sP}$; $\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_q L^q$; and $\theta_s(L^s) = 1 + \theta_{s1} L^s + \cdots + \theta_{sQ} L^{sQ}$. In other words, in addition to the regular AR and MA operators, there are operators in seasonal powers of the lag operator. Note that in practice, deterministic terms may added to equations (1) to (4) such as constant term and/or a trend.

For the purpose of this study, the first 83 observations (from January 2004 to November 2010) are utilized to estimate the SARIMA model to forecast the number of swine slaughtered after the FMD outbreak for the following 25 months (i.e., till December 2012). We then compare the forecasted number of swine slaughtered ("counterfactual") with the actual number of swine slaughtered.

The order of first differencing, represented by the value d in *SARIMA*(p,d,q)(P,D,Q)$_s$, is determined according to a non-stationary test, specifically the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the KPSS test (Kwiatkowski *et al.,* 1992) explained in the following section. The order of seasonal differencing, represented by the value of D, is determined by applying the HEGY test (Hylleberg, *et al.,* 1990), once again described in the following section. The optimal combination for the values of p, q, P, and Q are determined by minimizing certain loss

[2] ARMA(1,1), for example, is written as $y_t = \phi_1 y_{t-1} + \varepsilon_t + \theta_1 \varepsilon_{t-1}$ or $(1 - \phi_1 L)\, y_t = (1 + \theta_1 L)\, \varepsilon_t$.

[3] ARIMA(1,1,1), for example, is given by $\Delta y_t = \phi_1 \Delta y_{t-1} + \varepsilon_t + \theta_1 \varepsilon_{t-1}$ or $(1 - \phi_1 L)\Delta y_t = (1 + \theta_1 L)\varepsilon_t$.

[4] For example SARIMA(1,1,1)(1,0,1)$_4$ model is given by $(1 - \phi_{41} L^4)(1 - \phi_1 L)\Delta y_t = (1 + \theta_{s1} L^4)(1 + \theta_1 L)\, \varepsilon_t$ or $\Delta y_t = \phi_1 \Delta y_{t-1} + \phi_{41} y_{t-4} - \phi_1 \phi_{41} \Delta y_{t-5} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_{s1} \varepsilon_{t-4} + \theta_1 \theta_{s1} \varepsilon_{t-5}$.

function(s); for example, Akaike information criterion (AIC) or Bayesian information criterion (BIC).

Estimation and forecasting

The purpose of identification is to transform the non-stationary time series into a stationary series by differencing, if necessary. As shown in Figure 1, however, the number of swine slaughtered until November 2010 seems to be stationary without a trend even though there might exist some degree of seasonality. As mentioned before, the first 83 observations (from January 2004 to November 2010) are utilized to estimate the SARIMA model. To observe the stationarity of the series, ADF[5] and KPSS[6] tests on the number of swine slaughtered are conducted and results are reported in Table 1. As shown in Table 1, both tests confirm that the number of swine slaughtered is stationary, i.e., d = 0.

To see if there exists any seasonality, the autocorrelation functions (ACF) and the partial autocorrelation functions (PACF) for the series are plotted in the first row of Figure 2. The ACF has a significant spike at lag 1 which suggests non-seasonal MA(1) component. Also, a significant spike at lag 11 (and 12) in the ACF suggests seasonal MA(1) component. There might be AR(1) component because the PACF plot has a significant spike at lag 1. The ACF and the PACF are plotted for the series after performing a seasonal difference, i.e., $\Delta^{12} y_t = y_t - y_{t-12}$ and presented in the second row of Figure 2. The ACF and PACF here indicate that there exists a clear seasonal MA(1) component in the model.

Table 1: Non-stationarity tests for the number of swine slaughtered from Jan 2004 to Nov 2010.

Raw data	ADF test (non-zero mean)	KPSS Test (level stationary)
Test stat.	-4.409	0.197
Lags[a]	1	3
5% critical value	-2.89	0.463
Decision[b]	Reject null	Fail to reject null
	S	S

[a] Lags for ADF test is determined by minimizing BIC and for KPSS test is given by Newey-West lags, $\{4(T/100)^{\frac{2}{9}}\}$, where T is the number of observations
[b] ADF test - testing the null hypothesis of nonstationarity, thus the series is stationary by rejecting null hypothesis, KPSS test - testing the null hypothesis of stationarity, thus the series is stationary by failing to reject null hypothesis, and NS = nonstationary, S = stationary.
Source: authors' calculation; critical values are taken from Davidson and MacKinnon (1993)

To check for the existence of the seasonal unit root (whether $D = 0$ or not), the HEGY test (Hylleberg, *et al.,* 1990) is performed. The HEGY test was originally developed for quarterly data, and was extended for the monthly data by Franses (1991), and Beaulieu and Miron (1993). The HEGY test for monthly data is based on the following regression as explained in Rodrigues and Osborn (1999):

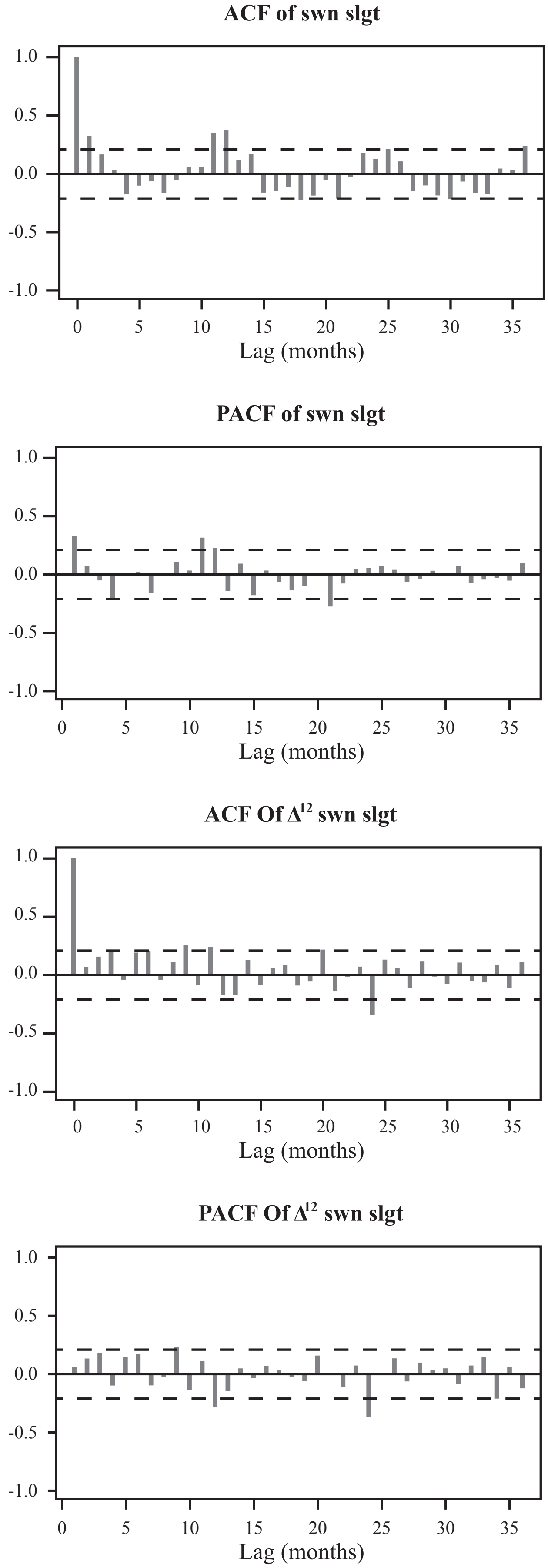

Figure 2: Autocorrelations and partial autocorrelations.
Source: authors' calculation

5 To compute the test statistics, we fit the regression, $\Delta y_t = \alpha + \beta y_{t-1} + \delta t + + \sum_{j=1}^{k} \zeta_j \Delta y_{t-j} + e_t$, via least squares and test H_0: $\beta = 0$ against H_A: $\beta < 0$.
6 The KPSS test is based on the regression, $y_t = r_t + e_t$, that breaks up a series into a random walk $r_t = r_{t-1} + vt, vt \backsim \text{iid}(0, \sigma_v^2)$ and a stationary error (e_t). If the variance is zero, σ_v^2, then $r_t = r_0$ for all t meaning that y_t is stationary.

$$\Delta^{12} y_t = \mu_t + \sum_{i=1}^{12} \pi_i x_{i,t-1} + \sum_{j=1}^{p} \phi_j \Delta^{12} y_{t-j} + \varepsilon_t \qquad (5)$$

where $x_{i,t-1}$ are linear transformation of lagged values of y_t (see Beaulieu and Miron, 1993, page 308, for the list of $x_{i,t-1}$). The null hypothesis implies that $\pi_1 = 0$, $\pi_2 = 0$, $\pi_{k-1} = \pi_k = 0$ for k = 4,6,8,10,12 (joint F test) (Rodrigues and Osborn, 1999). To control the overall level of significance for the aforementioned null hypotheses, Taylor (1998) added the null hypotheses, $\pi_1 = \cdots = \pi_{12} = 0$ and $\pi_2 = \cdots = \pi_{12} = 0$. Results are reported in Table 2. As shown in Table 2, there is no seasonal unit root and, therefore, $D = 0$.

Identification steps discussed in identification section suggests $d = 0$ (series is stationary) and $D = 0$ (series doesn't have seasonal unit root). The ACF and the PACF suggest non-seasonal MA(1), seasonal MA(1), and non-seasonal AR(1) components. All told, the initial candidate model is SARIMA$(1,0,1)(0,0,1)_{12}$. We estimated different specifications (Table 3). As shown in Table 3, the final model is SARIMA$(1,0,0)(0,0,1)_{12}$ which has the minimum value of BIC. The estimation result is in Table 4 with standard errors in parentheses.

A portmanteau test is performed after estimating the model in Table 4 to confirm that the residuals from SARIMA$(1,0,0)(0,0,1)_{12}$ are uncorrelated. If there are correlations between residuals, then there is information left in the residuals (Hyndman and Athanasopoulos, 2013). The Ljung-Box[7] test confirms that the residuals are uncorrelated (test statistics = 14.38 and p-value = 0.28 when lag = 12).

The SARIMA model in Table 4 is used to forecast the number of swine slaughtered for periods after the FMD outbreak, covering from December 2010 to December 2012. The predicted values are subsequently compared to the actual values. Figure 3 shows the sequence of forecasts (solid grey line) for the number of swine slaughtered each month, including its 95% confidence interval (dotted grey lines), and the actual number of swine slaughtered (dark line). Note that the forecasts of future values will eventually converge to the mean and stay there because the number of swine slaughtered is a stationary process (see Table 1) as shown in Figure 3.

Actual values, estimated (forecasted) values, the difference of them and the percentage of difference are reported in Table 5. Note that this difference in the number of swine slaughtered between December 2010 and February 2011 should be considered as the explicit cost. As indicated in KREI (2011, page 53 and Figure 2-3), the FMD outbreak occurred on November 28, 2010 and the number of affected animals increased very fast until the end of January 2011. The number of newly affected animal was one head per day in February 2011 once the second vaccination was completed. The reduction of swine slaughtered between December 2010 and February 2011 is removed from the calculation of the implicit cost, which consists of the accounted or explicit cost. We use the term implicit cost in the paper to refer to the unaccounted economic impact that is persistent after containing the FMD outbreak at the end of February 2011.

[7] The Ljung-Box test is based on $Q = T(T+2)\sum_{k=1}^{h}(T-k)^{-1} r_k^2$, where r_k is the autocorrelation for lag k and T is the number of observations. Large values of Q suggest that the autocorrelation do not come from a white noise series (Ljung and Box, 1978).

Table 2: Seasonal unit root test for number of swine slaughtered between Jan 2004 and Nov 2010.

Null hypothesis	Test Stat	p-value	Decision at 10%	
$\pi_1 = 0$	-1.100	0.629	Fail to reject	A unit root exists
$\pi_2 = 0$	-2.199	0.019	Reject	No unit root exists
$\pi_3 = \pi_4 = 0$	1.052	0.341	Fail to reject	A unit root exists
$\pi_5 = \pi_6 = 0$	1.836	0.155	Fail to reject	A unit root exists
$\pi_7 = \pi_8 = 0$	2.413	0.087	Reject	No unit root exists
$\pi_9 = \pi_{10} = 0$	5.772	0.004	Reject	No unit root exists
$\pi_{11} = \pi_{12} = 0$	4.642	0.011	Reject	No unit root exists
$\pi_1 = \pi_2 = \cdots = \pi_{12}$	3.446	0.014	Reject	No unit root exists
$\pi_2 = \cdots = \pi_{12}$	3.611	0.005	Reject	No unit root exists

Note: Constant is included in equation (5). Other specifications are possible such as adding seasonal dummies (not reported here to save space). Results are available upon request. In case of adding seasonal dummies, we fail to reject the null hypothesis only for the first case, $\pi_1 = 0$, and reject all other null hypotheses.
Source: authors' calculation

Table 3: SARIMA model and values of Bayesian Information Criteria.

Model		BIC
SARIMA$(1,0,1)(0,0,1)_{12}$	(Initial candidate)	-148.05
SARIMA$(0,0,1)(0,0,1)_{12}$		-150.42
SARIMA$(10,1)(0,0,2)_{12}$		-143.78
SARIMA$(1,0,1)(1,0,1)_{12}$		-143.78
SARIMA$(1,0,0)(0,0,1)_{12}$	(final model)	-151.63
SARIMA$(1,0,2)(0,0,1)_{12}$		-144.76

Source: authors' calculation

Table 4: SARIMA$(1,0,0)(0,0,1)_{12}$ regression result.

	Coefficient	Std. Err.
Non-seasonal AR(1)	0.2554***	(0.1023)
Seasonal MA(1)	0.5631***	(0.1244)
Constant	1.1675***	(0.0204)
σ_ε	0.0849***	(0.0061)
No. obs.	83	
Log likelihood	84.65	
BIC	-151.63	

Note: The test of the variance against zero is one sided
Source: authors' calculation

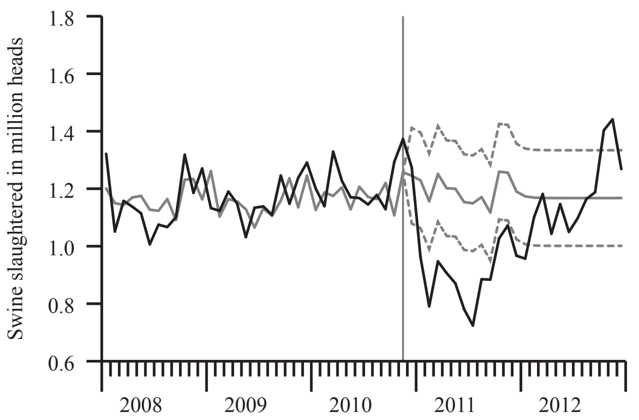

Figure 3: Actual and forecasted number of swine slaughtered.

Dark line = actual number of swine slaughtered; Grey line = forecasted number of swine slaughtered; Dotted line = 95% confidence bands
Source: actual number of swine slaughtered is compiled from Animal and Plant Quarantine Agency, Korean Ministry of Agriculture, Food, and Rural Affairs; forecasted number of swine slaughtered is calculated using SARIMA estimates in Table 4.

Between March 2011 and October 2011, the loss in the number of swine slaughtered due to the persistent FMD outbreak is approximately 2.17 million heads (between 0.95 million heads ~ 3.4 million heads). We consider October 2011 as the end of forecasting horizon, and compute the loss in the number of swine slaughtered, because the actual number slaughtered rebounded up and reached the lower 95% confidence level in October 2011. The difference between the actual and forecast values still exist after October 2011, but it is not evident that this may be solely because of the FMD outbreak.

Note that Korea-EU Free Trade Agreement (FTA) has been provisionally applied since July 2011 (and formally ratified in December 2015), which may have increased pork imports from the EU due to the lowered tariff; and in turn, potentially have affected the number of swine slaughtered. In other words, the loss in the number of swine slaughtered during August-October 2011 might be overestimated. Pork imports from the EU increased by 50%, to 208,271 tons in 2011 from 139,343 tons in 2010 (Table 3 in Han *et al.,* 2016). Perhaps this increase in pork imports is partly because of the 2010 FMD outbreak and also partly because of Korea-EU FTA. Unfortunately, it is very difficult to distinguish among these two possible causes. We argue that a sharp increase in pork imports from the EU in 2011 responded more to the late November 2010 FMD outbreak, rather than to the July 2011 Korea-EU FTA, for the following two reasons.

First, pork imports from the EU in 2012 (second calendar year of Korea-EU FTA, or its first full year of FTA implementation) decreased to prior 2010 levels, that is, 125,446 tons. Moreover, pork imports in 2013 (third calendar year of Korea-EU FTA, or its second full year of FTA implementation) reached 148,558 tons (Table 3 in Han *et al.,* 2016), which was after the swine inventory had rebounded. Second, pork is the most sensitive product in the FTA and it has a 10-year transition period until having duty free access. The tariff rate before FTA was 25% for frozen pork belly and 22.5% for fresh pork belly, which means that the tariff rate in 2011 was 22.7% for frozen pork belly and 20.4% for fresh pork belly (Moon *et al.,* 2013a). Thus, the drop-in tariff rate impact for 2011 from the FTA would be minimal, if any. In addition, Moon *et al.* (2013a) indicate that "… 2010 FMD outbreak has resulted in a sharp increase in pork imports from the EU… and pork imports from the EU decrease in the second year, after domestic supply has recovered …" (Moon *et al.,* 2013a, page 5).

To estimate the implicit cost of 2010 FMD in Korea, the loss in the number of swine slaughtered is multiplied by the average swine price received by farmers in 2010 (mostly before the FMD outbreak), which was 328,000 Won/110kg (≈ 295 US dollars/110kg) (eKAPEPIA price information, Korea Institute for Animal Products Quality Evaluation (KAPE)). According to eKAPEPIA (http://www.ekapepia.com/637.su) the swine price received by farmers had not varied much during the years 2008-2010. However, swine prices increased substantially after the FMD outbreak, to more than 480,000/110kg (≈ 432 US dollars/110kg). We conjecture that the swine price received by farmers would not have changed substantially in the first quarter of 2011 if the FMD outbreak had not occurred in November 2010.

As a result, the estimated implicit direct cost of FMD is 713 ± 402 billion Korean Won (642 ± 362 million US dollars). Implicit indirect and induced economic impacts can be computed using the standard Input-Output multipliers as in KREI (2011) and Moon *et al.* (2013b). The implicit indirect cost is estimated to be 947 ± 534 billion Korean Won (≈ 852 ± 481 million US dollars) using the standard IO multipliers for the swine sector from Bank of Korea (2014). The implicit induced cost is estimated to be 447 ± 252 billion Korean Won (≈ 402 ± 176 million US dollars). As such, the total implicit cost is estimated to be 2,107 ± 1,189 billion Korean Won (1,896 ± 1,070 million US dollars). As discussed, this is the cost Korea must give up, or cannot recover, due to the FMD outbreak.

Concluding remarks

This research begins with a question regarding the implicit cost (persistent cost) of livestock disease, focusing on 2010 FMD outbreak in Korea. These implicit costs can be estimated by comparing the level of livestock slaughtered during a FMD outbreak (i.e., "the treatment group") to the number of livestock slaughtered if there is no FMD outbreak (i.e., "a control group" or counterfactual scenario of no FMD). In doing so we estimate the cost equal to what we must give up because of the FMD outbreak. Given the difficulties associated with identifying a control group, we use the seasonal autoregressive-moving average to estimate counterfactual number of livestock slaughtered. The focus of the study is on the swine sector in Korea, and find that up to October 2011, the accumulative difference in the number of

Table 5: Actual and forecasting values of number of swine slaughtered after FMD outbreak.

Quarter/Year	Actual	Forecasts	Difference	Difference (%)
		(million heads)		
Mar 2011	0.947	1.251	-0.304	-32.1
Apr 2011	0.906	1.202	-0.295	-32.6
May 2011	0.871	1.200	-0.329	-37.8
Jun 2011	0.781	1.154	-0.373	-47.7
July 2011	0.724	1.149	-0.425	-58.7
Aug 2011	0.885	1.171	-0.286	-32.3
Sep 2011	0.884	1.117	-0.233	-26.4
Oct 2011	1.027	1.259	-0.232	-22.6

Source: actual number of swine slaughtered is compiled from Animal and Plant Quarantine Agency, Korean Ministry of Agriculture, Food, and Rural Affairs; forecasted number of swine slaughtered is calculated using SARIMA estimates in Table 4.

swine slaughtered was estimated to be more than 2 million head. The approximated implicit direct cost of FMD is 713 billion Korean Won (≈ 642 million US dollars). The implicit indirect and induced cost from this are estimated to be 947 billion Korean Won (≈ 852 million US dollars) and 447 billion Korean Won (≈ 402 million US dollars), respectively; by using the standard IO multipliers for the swine sector from Bank of Korea (2014). The total implicit cost is estimated to be 2,107 billion Korean Won (1,896 million US dollars).

This paper contributes to the literature on quantifying the effects of livestock disease in a regional economy where there is no study up to this date regarding the implicit cost of a livestock disease outbreak. The swine sector in Korea is analysed to estimate the implicit cost of the FMD outbreak in 2010. Results consider economic losses that were not previously accounted for. This study serves to strengthen the justification of applying preventive efforts to reduce the likelihood and economic impact of an animal disease outbreak. In addition, the study's approach is applicable to other hypothetical or actual cases of potential disease outbreaks, as is the plausible case of ASF in Europe. Suggesting policy options to mitigate negative economic impacts of the FMD outbreak may be beyond the scope of this study. However, livestock and meat traceability system may be a way to improve preventive controls of the animal disease outbreak. Animal and meat traceability as a mandatory system would have been useful to track livestock movements in a pertinent country or region (e.g. EU) by establishing an identification number for premises where livestock were located, assigning animals an identification number (either individual or group), and implementing a national, electronic database for livestock tracking. It has been supported by the animal health community (Kim *et al.*, 2017; Bailey, 2007; Bailey and Slade, 2004; Lawrence, 2004) who have viewed such a system as being an important component for tracking, controlling, and eradicating animal disease outbreaks.

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