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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 counterintuitive 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

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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:

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

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:

$$\varepsilon_i = v_i - u_i, \qquad u_i \geq 0 \quad (2)$$

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):

$$v_i \sim iidN(0, \sigma_v^2) \quad (3)$$

$$u_i \sim iidN^+(0, \sigma_u^2) \quad (4)$$

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

$$u_i = \delta z_i + \omega_i \quad (5)$$

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)

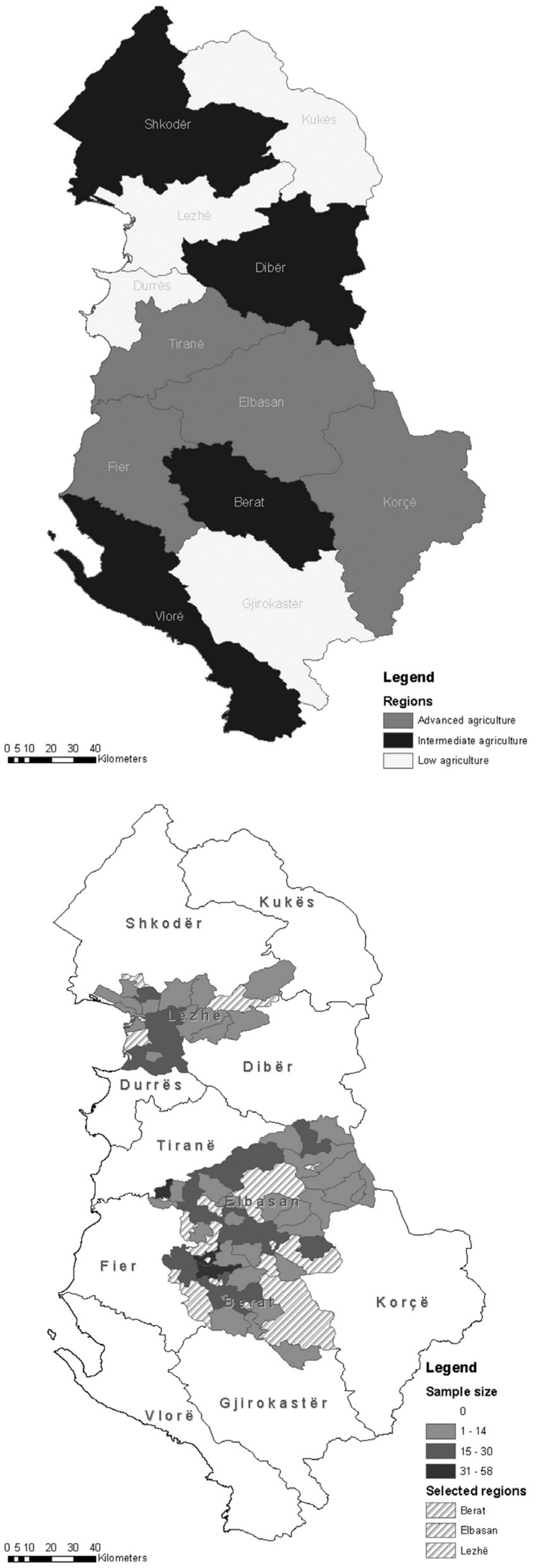

Figure 1: The classification of the regions and the distribution of the sample among the selected regions and communes.
Source: Guri *et al.* (2015)

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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