Land use fragmentation and technical efficiency of Austrian crop farms

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***Abstract* - For developing countries, a vast literature on the effects of land use fragmentation (LUF) on farm performance and its implications for land consolidation programs exists. However, little is known about the relationship between LUF and farm performance in Western and Central European countries. We use plot-level data from the Austrian Integrated Administration and Control System to derive a set of LUF indices at the farm-level. We explore the relationship between these LUF indices and technical efficiency of Austrian crop farms. We find statistically significant, though moderate efficiency-decreasing effects of a higher number of plots, lower average plot size and a larger distance from the farmstead to the most remote plot on technical efficiency. At the same time our results indicate no statistically significant effect of the scattering of plots and the average farmstead-plot distance on technical efficiency. Land consolidation programs should not only consider the efficiency losses from LUF incurred by farmers, but also the potential public costs and benefits of LUF.**

INTRODUCTION

Agricultural LUF encompasses many different dimensions including: 1.) (average) plot size; 2.) number of plots farmed; 3.) shape of plots; 4.) distance of plots from farmstead; and 5.) distances between plots (or plot scattering) (Latruffe and Piet, 2014). LUF can have different costs and benefits for farmers: i.) higher transportation costs for inputs and outputs; ii.) higher labour requirements due to travelling time and organizational issues; iii.) less possibilities to exploit economies of scale (e.g., reduced field-efficiency of machinery and limited uptake of innovations); and iv.) harvest loss along field boundaries and at corners. While costs subsumed in i.) and ii.) are more related to dimensions 3.), 4.) and 5.), costs described in iii.) and iv.) are related to dimensions 1.) and 2.). However, there are also possible positive effects of LUF, which are mainly connected to the number of plots, including: cropping pattern optimization by better matching crops and plot attributes (e.g., soil); reduced production risk (e.g., from flood and hail); and reduced price risk (due to product diversification). The aim of this article is to investigate if LUF has a positive or negative impact on the technical efficiency of Austrian crop farms. A solid body of empirical literature on the effects of LUF on different dimensions of economic performance exists. However, most of these studies focus on developing or transition countries (e.g., Albania, Bulgaria, Estonia, North Macedonia). To the best of our knowledge the only studies investigating the effect of LUF on farm performance in Western European countries are Latruffe and Piet (2014) for Brittany, France, Olsen et al. (2017) for Denmark, and Heinrichs et al. (2021) for Germany. While Heinrichs et al. (2021) provide a case study for three farms located in Western Germany, Latruffe and Piet (2014) and Olsen et al. (2017) offer large-scale analyses. For most LUF indices, except for indices measuring the shape and scattering of plots, Latruffe and Piet (2014) find a significant negative relationship between LUF and technical efficiency. Olsen et al. (2017) find that the shape of fields has no statistically significant effect, while smaller field sizes and longer distances significantly reduce farm performance.

DATA AND METHODS

We merge two datasets: First, we use farm bookkeeping data from the Austrian section of the FADN to calculate production input and output variables, i.e., capital (in 2009 Euros), land (utilized agricultural area in ha), labour (annual working units), intermediate inputs including expenditures for fertilizer, pesticides, energy and others (in 2009 Euros), and revenues (in 2009 Euros). We use the four inputs and the single output to estimate technical efficiency scores with a standard radial Data Envelopment Analysis model (Charnes et al., 1978). We allow production frontiers to vary across time. The technical efficiency measures take values between 0 and 1, where 1 indicates that a farm is efficient. Second, we use plot-level data of the Integrated Administration and Control System to calculate a) the number of plots per farm, b) a farm's average plot size (in ha) and c) the Euclidian distance between the farmstead and the most remote plot (in km). The sample for our analysis consists of farms generating more than 50 % of annual revenues with crops and is restricted to the years 2009-2012. We regress each LUF index separately on the technical efficiency scores and control for average farm-plot characteristics (avg. altitude, avg. slope, avg. soil quality), farmer characteristics (age, gender, education), farm size and time fixed effects. We estimate pooled regression models with Ordinary Least Squares (OLS) and standard errors cluster at the farm-identifier. **Table 1** provides summary statistics of technical efficiency estimates and the LUF indices.

Table 1. Data used in analysis

LUF index	Mean	SD	Min	Max
Technical efficiency	.58	.20	.03	1.00
Number of plots	41	30	6	320
Average plot size (ha)	1.5	0.7	0.2	5.3
Max. farmstead-plot dist. (km	5.6	4.6	0.2	34.5

Based on ~ 1260 obs. for the years 2009-2012.

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The average technical efficiency is 0.58. On average, a farm has 41 plots with a size of 1.5 ha, and the most remote plot being located 5.6 km from the farmstead.

RESULTS

Table 2 shows the results of the pooled-OLS regression models. To save space, we do not report coefficient estimates and standard errors of control variables. The coefficient estimates of the LUF indices indicate that more fragmented farms tend to be less technically efficient: Model (1) reveals that one additional plot decreases technical efficiency by 0.001. The effect is statistically significant at the 1 % level. Model (2) shows that an increase of the average plot size by one hectare is associated with an increase of technical efficiency by 0.037. Finally, model (3) suggests that if the distance from the most remote plot to the farmstead increases by one km, the technical efficiency declines by 0.003. The statistical significance of this effect is weaker than for the LUF indices tested in Model (1) and (2) but we can reject the hypothesis that this effect is equal to zero at the 10 % significance level. LUF indices tested but not reported in **Table 1** and **Table 2** include the weighted (by plot size) average farmstead-plot distance and an index capturing the scattering of plots (average nearest neighbour distance). While the estimated coefficients are negative for both measures, our analysis suggests that these effects are statistically insignificant.

Table 2. Pooled-OLS regression results

LUF index	(1)	(2)	(3)
Number of plots	-.001***		
	(.0003)		
Average plot size (ha)		.037***	
		(.0112)	
Max. farmstead-plot dist. (km)			-.003*
			(.0016)
Observations	1252	1252	1251
Number for farms	374	374	373
Adjusted R^2	0.23	0.23	0.22

*** p<0.01, ** p<0.05, *p<0.10. Dependent variable is technical efficiency. Coefficient estimates are reported with standard errors clustered at farm-identifier in parenthesis.

Note that our results should be interpreted with caution and might not represent a causal relationship, especially if more efficient farmers are more likely to reduce fragmentation. Other methodological limitations are: First, little within variation for most of our variables makes it difficult to apply farm-fixed effects that control for time-invariant, farm-specific heterogeneity beyond the control variables included in our models, leaving some chance for omitted variable bias. Second, we do not control for regional time-variant effects such as (extreme) weather (events). Third, recent literature argues that LUF could be endogenous (see e.g. Knippenberg et al., 2020) and determined by, e.g., farmers' ability or conscious choices of farmers, both potentially affecting farm performance.

CONCLUSION

Regarding the efficiency-decreasing effects of a larger number of plots, lower plot size, and (to a certain extent) larger farmstead-plot distances, our findings are in line with Latruffe and Piet (2014) and Olsen et al. (2017). However, policy recommendations for land consolidation programs should not only take into account the private costs of LUF for farmers, but also public costs and benefits associated with LUF. On the one hand, additional and longer trips by farmers may result in additional traffic, road safety issues, and CO_2 emissions. On the other hand, smaller fields, in particular those with hedges or other landscape components between plots, may increase ecosystem services, biodiversity, and landscape characteristics. Moreover, fragmented plots may increase crop diversity, which in turn may strengthen the ecosystem.

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