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# Evaluating the double effect of land fragmentation on technology choice and dairy farm productivity: A latent class model approach

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ABSTRACT

Land fragmentation affects dairy farming through its influence on foodstuff production. As its impact on extensive farms (which use a large land area per cow) is expected to be larger than on intensive farms, land fragmentation could also constitute an obstacle to adopting an extensive production technology. Given that extensive farming is being encouraged by direct payments from the Common Agricultural Policy to protect the environment and preserve rural heritage, land fragmentation may reduce the effectiveness of this rural development aid. We provide an empirical application using a sample of Spanish dairy farms located in a region where land is highly fragmented. Using a stochastic frontier latent class model, we find a significantly larger impact of land fragmentation on the productivity of extensive farms compared to intensive ones. Moreover, land fragmentation significantly reduces the probability of using extensive production processes. Our simulation analyses shows that a reduction in the number of plots similar to that already achieved by previous land consolidation processes in the region would improve the variable profits of extensive farms by 16% compared to 6% for intensive farms. Additionally, up to 84% of intensive farms would switch to extensive production processes.



## Introduction

Land fragmentation, in which a single farm uses several parcels of land, is a common feature in many countries (Blarel et al., 1992; Wan and Cheng, 2001; Dijk, 2003). This characteristic is usually expected to have a negative effect on farms' productivity due to several reasons: (1) fragmentation causes an increase in traveling time between fields which induces both lower labor productivity and higher transport costs for inputs and outputs; (2) it reduces the efficiency of machines compared to that obtainable in large, rectangular fields (Buller and Bruning, 1979); (3) land is lost when forming plot boundaries and access routes; and (4) it gives rise to the need for additional machinery, secondary buildings or external service expenses. As a consequence, land consolidation processes have been established around the world to avoid the negative impact of land fragmentation on agricultural productivity (Vitikainen, 2004; Niroula and Thapa, 2005; Pasakarnis and Maliene, 2010).

On the other hand, land fragmentation (LF hereafter) is also expected to have some benefits for farmers. For instance, farmers could take advantage of differences in both elevation and soil type as crops at lower elevations mature earlier than those at higher elevations, and plots with different soil types permit a farmer to produce a more diversified portfolio of crops. Differences in elevation and soil type would thus allow the synchronization of harvests with available family labor, thereby reducing requirements for hired labor. Additionally, LF is expected to reduce production risk associated with the influence of hailstorms, floods or fire.

The empirical literature measuring the effect of LF on agricultural production has been growing in recent years but remains quite small. Among the main contributions are Falco Di et al. (2010), del Corral et al. (2011), and Latruffe and Piet (2014) for Europe; Nguyen et al. (1996), Wan and Cheng (2001), Carter and Estrin (2001), Tan et al. (2010) for China; and Parikh and Shah (1994), Jabarin and Epplin (1994), Wadud and White (2000), Rahman and Rahman (2008), Kawasaki (2010), Manjunatha et al. (2013) for Asian countries other than China. While most papers examine this issue by including an LF measure as an additional input in the farm's production function (Wan and Cheng, 2001; Wu et al.,

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2005), Wadud and White (2000), Rahman and Rahman (2008) and other studies use the Stochastic Frontier Approach (SFA) to analyze its effect on farms' productivity (i.e. efficiency).[3] Most empirical studies conclude that fragmentation negatively affects agricultural productivity (Wan and Cheng, 2001; Rahman and Rahman, 2008) but in some cases LF has been found to have a non-significant effect on agricultural production (Wu et al., 2005). Therefore, it seems that the effect of LF could depend on the characteristics of the production process analyzed.

Focusing on milk production, del Corral et al. (2011) found a negative impact of LF on farms' productivity and profitability, which suggests that LF generates some difficulties for foodstuff production inside the farm. In this study we try to extend the empirical study carried out by del Corral et al. (2011) by testing two additional, but related, hypotheses. First, we analyze whether the effect of LF is larger for *extensive* farms – which use a large proportion of self-produced feed and are usually characterized by high values of land per cow and low values of concentrates per cow – than for *intensive* farms, which use a large proportion of purchased foodstuff (Alvarez et al., 2008; Alvarez and del Corral, 2010). Second, as LF is expected to be more relevant for extensive farms and the choice of production process is not external to dairy farmers (i.e., it is an endogenous decision), we also examine whether LF has conditioned the current choice of production process. In particular, our approach allows us to examine whether farms have tended to select more intensive methods as the degree of LF increases.

Both farmers and policy makers are likely to find the empirical results of this paper relevant. Regarding farmers, the degree of market competition is expected to increase due to the disappearance of milk quotas in 2015, and the probable reduction in milk prices could compromise the economic viability of dairy farms. Therefore, improving farms' technical efficiency could be necessary to permit the farms to survive. Additionally, intensive dairy production is profitable when a large production per cow compensates the large expenditure on (purchased) concentrates. This often occurs when the ratio between the price of milk and the price of concentrates is high. However, given that feeding costs (most of which are concentrate purchases) represent 80% of variable costs, farms will likely be forced to adopt more extensive systems of milk production in order to use more self-produced foodstuff if the milk price falls. The struggle for survival will thus likely rely on improving farms' technical efficiency and adopting extensive production processes, and both may depend on the degree of LF.

Furthermore, as extensive production processes generate lower ground and water pollution (Haas et al., 2001; Basset-Mens et al., 2009), the Common Agricultural Policy includes actions to provide incentives for its adoption by dairy farmers (Council Regulation No. 74/2009). In this sense, our results on the choice of intensive or extensive production processes contribute to our understanding of whether LF is indeed an obstacle to adopting less polluting production processes.

To carry out our analysis we propose using a latent class stochastic production frontier model. The model is estimated using a sample of Spanish dairy farms located in Asturias, a region in the northwest of Spain where land is highly fragmented. To illustrate this, the Agrarian Census conducted in 1999 (Agrarian Censuses are performed every ten years and the last one including the number of plots per farm is that from 1999) shows that the average number of plots per farm in Asturias was 12.5 (INE, 2014a).[4] Our empirical strategy allows both the identification of the technological differences between intensive and extensive dairy farms as well as the measurement of the impact of LF on the choice of a milk production system. In addition, the frontier nature of the milk production function allows an assessment of the impact of LF on the technical efficiency of extensive and intensive farms. Finally, several simulation exercises are also performed to analyze the effects of a potential reduction in the number of plots due to a hypothetical land concentration process.

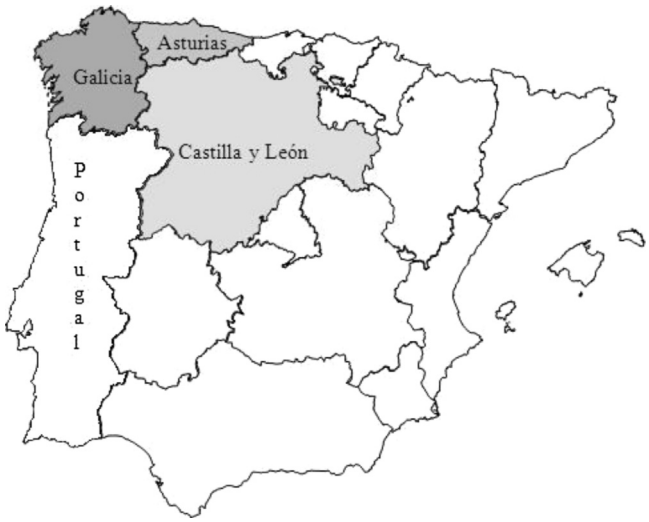


**Fig. 1.** Main milk production regions in Spain.

## LF in the northwest of Spain

LF is a characteristic frequently observed around the world, particularly in Europe and Asia as a consequence of several factors including inheritance laws, transaction costs in land markets and urban development policies (King and Burton, 1982; Blarel et al., 1992). Although the degree of LF is high in some of the main milk producers of the European Union such as France (Latruffe and Piet, 2014), Poland (Hartvigsen, 2014), Spain (Maceda, 2014) or Ireland (O'Donnell et al., 2008a,b), there is a lack of empirical research analyzing this issue in the context of milk production (a notable exception is del Corral et al., 2011). We consider it appropriate to carry out such an analysis as important land consolidation processes have been implemented in recent decades to ameliorate the degree of LF in some of the main European milk producers such as Germany (Mayhew, 1970), the Netherlands (Vitikainen, 2004), or Spain (Crecente et al., 2002; Miranda et al., 2006; Maceda, 2014).

Milk production in Spain is concentrated in the northwest quadrant of the country (Fig. 1), with the Autonomous Communities of Galicia, Castilla y León and Asturias responsible for 60% of overall Spanish milk production in 2012 (INE, 2014b). In this sense, it is worth noting that Galicia, the largest producer and which accounts for 39% of Spanish milk production, is also the Autonomous Community with the greatest degree of LF in Spain (Maceda, 2014).

Despite the reduction in the number of dairy farms in the northwest of Spain since its incorporation into the European Union in 1986, farmers find it difficult to expand their land. For instance, López (1995) analyzes land transactions in Galicia and concludes that only 0.35% of the total agricultural surface is acquired yearly by farmers to expand their land area. This small percentage is likely caused by several factors. First, land may not be so readily available because exiting farmers may use the land for other purposes (in many cases, for beef cows); second, the legal costs associated with changes in the Land Registrar are very expensive in Spain; and

[3] Technical efficiency is measured in this literature as the ratio between the actual production and the one attained by fully exploiting the technological potential.

[4] INE (Instituto Nacional de Estadística) is the official Spanish Bureau of Statistics and collects data on many social and economic activities in Spain.