ECONOMIC DISCUSSION PAPERS

Efficiency Series Paper 4/2019

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Available online at: http://economia.uniovi.es/investigacion/papers

Rural and agricultural development by land consolidation: a spatial production analysis of Asturias´ parishes [(a), (b)]

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March 18, 2019

Abstract

The objective of this research is to evaluate the impact of the land consolidation (LC) processes that have taken place in Asturias during the period 2001-2017. We base our estimation in a production approach using parishes' dairy and beef herd as proxies for livestock production and several LC-based variables that aim to capture the quantity and intensity of the LC processes implemented in each parish. In addition, we analyse the effect of LC on the number of farms using auxiliary regressions. We find an annual effect of about 2.1% on parishes' livestock production attributed to LC processes in Asturias, which has mainly benefited parishes with dairy and mix-oriented farms. This positive effect increases over time, and it is larger in coastal parishes and in parishes with more traditional farms. We also find that the (indirect) effect from LC processes implemented in neighbouring parishes is positive and even more relevant than the (direct) effect on the local LC processes. Overall these results advocate using coordinated LC measures by the regional governments in order to take full advantage of this important policy.

Keywords: Land consolidation, Agricultural development, spatial spillovers

JEL codes: C21, C23, D24, Q15

(a) The content of this paper will be published as a chapter in the forthcoming Springer's book "Advances in Efficiency and Productivity II".

(b) We would like to thank the financial support obtained from the Government of the Principality of Asturias and the European Regional Development Fund (ERDF). This working paper was also supported by the Spanish Ministry of Economics, Industry and Competitiveness (Project MINECO-18-ECO2017-85788-R).

1. Introduction

Land consolidation (LC) has been acknowledged as an effective instrument to add new farmland, improve land productivity and promote sustainable land use (see Zhou et al, 2019 and the references therein). It consists of two main components: land reallocation aiming to reduce land fragmentation (LF); rural planning that encompasses the provision of relevant infrastructure, e.g. roads and irrigation networks (Demetriou, 2018). LC Although LC policies usually had agricultural goals initially, they have increasingly become instruments of rural sustainable development in Europe and in many countries around the world (Crecente et al., 2002).

The studies on LC and its effects are of great interest to those responsible for designing agrarian and rural development policies as well as for farmers and rural inhabitants. See the Appendix for a summary of the most recent literature on this topic. The literature on LC presents multiple approaches, and it is also related to research on the effects of LF and on the efficiency and productivity of agricultural holdings.

The effect of LF on agriculture has worried policymakers for a long time because it is expected to be a negative effect. LC policies are frequently implemented to soften the degree of LF. LF is expected to affect farm production negatively for several reasons. LF causes an increase in traveling time between fields, which induces both lower labour productivity and higher transport costs for inputs and outputs; reduces the efficiency of machines use; and land is lost when forming plot boundaries and access routes. Most empirical studies conclude that fragmentation negatively affects agricultural production (Wan and Cheng, 2001; Rahman and Rahman, 2008). In the case of the dairy sector, Del Corral et al. (2011) evaluate the effect of LF on milk production in a sample of Spanish farms located in Asturias and found a negative influence of LF on milk production. Additionally, based on a previous paper, Orea et al. (2015) found not only a significantly larger impact of LF on the productivity of extensive farms compared to intensive ones, but also that LF significantly reduces the probability of using extensive milk production processes.

Regarding the LC literature, it generally finds that LC has exerted broad impacts on promoting agricultural production scale and increasing the competitiveness of agricultural products in Europe and other countries. For instance, Hiironen and Riekkinen (2016) evaluate a dozen of LC projects in Finland using standard statistical methods and production cost analyses. They found that LC improved the property structure and costs decreased 15%. Crecente et al. (2002) evaluate the economic, social and environmental effects by comparing consolidated and non-consolidated areas in Galicia, an autonomous region located in north-west Spain that is adjacent to the region examined in our paper (i.e. Asturias). A dominant traditional agricultural economy and a historical tradition of property inheritance by sub-division within families, have produced a high degree of LF in these two regions. They show that LC contributes to retaining farmland in agricultural use and improves the population evolution in rural areas, although they observe changes in use from cropland to pasture land. Also using very disaggregated geo-spatial data at parish-level, Miranda et al (2006) conclude that LC have improved agricultural land structure by reducing the number of plots per holding, have reduced the generalized decline in the number of active holdings and have reduced the decline in the population of rural areas.

In recent years there has been great interest in the study of the effects of LC processes in China. For instance, Wu et al. (2005) used a production function approach and farm-household data to evaluate the effectiveness of LC projects in China. They found that the LC processes have improved land quality and the productivity of household crop production. Using detailed geo-spatial information for a large set of Chinese LC projects, Jin et al. (2017) found however that the overall effectiveness of these LC processes in improving agricultural productivity is low, existing clear regional differences.

As pointed out by Crecente et al. (2002), there is no specific methodology that is generally accepted for the evaluation of LC. Our review shows that the methodologies used in this literature vary from country to country, due to lack of data availability (see, e.g. Hiironen and Riekkinen, 2016), differences in both data disaggregation (e.g. farm/household-level vs. geo-spatial data) and data collection (gathered via questionnaires or by the public administration involved in the LC processes), the existence of different objectives of land-use policy (land productivity, rural development, nature protection, etc.) or different categories of LC effects (e.g. agricultural production effects, transportation effects, effects on drainage and similar measures, the impact on ecological environment, or the social and regional economic effects). Furthermore, there are inconsistent conclusions on the impact of LC on several of the above categories. For instance, Zhou et al (2019) point out that while some studies showed that LC has a negative impact on the ecosystem services value and landscape diversity (see e.g. Zhang et al., 2014), other papers found a positive ecological effect (see e.g. Yu et al., 2010 and Hartvigsen, 2014).

In summary, there are studies that analyse the effects of LF and LC at a micro-level or farm level (Wu et al., 2005; Manjunatha et al., 2013; Orea et al., 2015; Nilsson, 2018), while others carry out the analysis at a spatial level, taking the municipalities or regions as units of study assessing the effect on spatial distribution of economic activities (Crecente et al, 2002; Du et al., 2018; Dudzińska et al., 2018), even focusing on the socio-economic improvement of rural areas and the reduction of poverty in these territories (Zhou et al., 2019).

This paper evaluates the impact of the LC processes that have taken place in Asturias in recent decades. As regional policy makers strongly believe that the high degree of LF in Asturias prevents local farms to be competitive, they have promoted the implementation of 279 public LC processes in this region since the 60s to soften the degree of LF. According to the information provided by the Principality of Asturias, the LC processes carried out in Asturias over this period have involved more than 28 thousand owners and about 60 thousand hectares of land, and the average investment amounts to 2,300 euros per hectare. Moreover, these processes have been able to reduce the number of plots from 224 to 58 thousand plots. These processes have been receiving European funds because of their potential to improve the economic activity in rural areas, increase farmer income, and stabilize their population.

Figure 1 shows the number of LC processes carried out in Asturias over the period 1963-2017. Notice that the number of LC processes has intensified since 2000. This large enforcement is likely caused by the new public LC mechanisms allowed by recent regulation in Asturias. In particular, the Legal Decree 80/1997 established the conditions under which farmers can request the regional government to initiate a LC process. This regulation avoids negotiation and legal costs and allows the public administration to change access routes to the new plots. On the other hand, and following the principles established in the Agrarian Regulation and Rural Development Law of 1989, the public administration itself can also promote a local LC process.[1]

[Insert Figure 1 here]

This paper evaluates the impact of a set of Asturian LC projects during the period 2001-2017 due to the large enforcement of the LC policy since 2000, and because there is not reliable data on parishes' farms activity in previous decades. The study is focused on western Asturias because, as shown in Figures 2 and 3, the LC processes were implemented with great intensity in the western municipalities and parishes of Asturias, especially since 2000. We also do not have information about public investment in many of the LC processes carried out in East Asturias.

[Insert Figures 2 and 3 here]

Like Wu et al. (2005), we use a production function approach to evaluate the effectiveness of the LC processes. However, while these authors use farm-household data, we use detailed geo-spatial data of Asturian parishes with and without LC processes, as in Crecente et al. (2002) and Miranda et al. (2006). We treat the parishes in Asturias as production units to evaluate the effect of LC processes on milk and beef production. Given the multi-output nature of the parishes' production technology we take advantage of the production theory and estimate a set of distance functions that can be viewed as multi-output productions functions. Due to lack of data, we use parishes' dairy and beef herd as proxies for both livestock production in each parish. In addition, we analyse the effect of LC on parishes' farm numbers using a set of auxiliary regressions. This allows us to compute, and decompose, an overall effect of LC on parishes' livestock production.

This work has been possible thanks to the availability of statistical information disaggregated by parishes on farms and livestock, as well as specific information on the quantity and the intensity of the LC processes, over a sufficiently long period of time. This allows us to use panel data estimators that control for many variables that are not available at parish level but likely time-invariant.

Unlike previous papers examining LC processes, we introduce spatial interdependence into our analysis by adding the LC indicators of neighbouring parishes. Given that we use very disaggregated spatial information, we expect substantial spatial spillover effects, understood as the benefits obtained by a parish when using the plots and infrastructures existing in other parishes. One stylized result from the regional economics literature is that the direct effect of own variables on production reduces when the territorial disaggregation of locations increases (i.e., administrative units are smaller), (see e.g. Álvarez-Ayuso et al, 2016). This happens in our application as our observations are parishes, i.e. Christian territorial entities that are much smaller than the standard municipalities (provinces) used in urban (regional) economics. For this reason, it is critical to take into account spatial spillovers effects when analysing the impacts of our LC indicators. There is a literature at micro-level (farms) that introduce spillover effects based on the idea that large farms can benefit neighbouring smallholders via different channels (Deininger and Xia, 2016; Ali et al., 2019). However, to the knowledge of authors, there are no studies that analyse these effects in the case of LC processes.

[1] The above two regulations can be found in the Asturias' Official Bulletin (https://sede.asturias.es/portal/site/Asturias/menuitem.048b5a85ccf2cf40a9be6aff100000f7/?vgnextoid=c0c756a575acd010VgnVCM100000bb030a0aRCRD&i18n.http.lang=es&calendarioPqBopa=true).

2. Empirical method

Our first empirical models aim to measure the economic impact of LC processes on parishes' livestock production using a primal representation of *parishes' production* technology. The effects estimated here can be interpreted as an effect on farms' average size because they are *conditional* on the number of farms of each parish. In order to get an overall effect, we next estimate a set of *auxiliary regressions* to examine the effect of our LC variables on the number of farms.

2.1. Parishes' production model

Our production models are inspired in three different but complementary approaches: i) the panel data estimators that control for unobserved heterogeneity; ii) the spatial econometric models that aim to capture indirect effects generated by LC processes in neighbouring parishes; and iii) the production theory that allows us to examine changes in parishes' dairy and beef production using a singly equation.

Regarding the first two approaches, Demetriou (2018) points out that the standard regression analysis in LC evaluations ignores two important issues: spatial heterogeneity and spatial dependence. Indeed, there are many characteristics that affect parishes' production, but which are unobserved at parish level or omitted variables (e.g., geographic conditions, population structure, distribution of economic activities, network characteristics). If these omitted variables are correlated with our regressors, we have an endogeneity problem. If this issue is ignored, we will get both biased parameters and biased effects attributed to LC processes. However, notice that many of the above unobservable variables are likely to be time-invariant or rarely changing variables. In this case, the endogeneity issue can be addressed by adding a set of parish-specific intercepts α_i that are treated as parameters to be estimated using a Fixed-Effect (FE) estimator.

It should be mentioned that the FE estimator only uses the temporal variation of the data to get the parameter estimates. In this sense, our empirical strategy to measure the effects of LC can be viewed as a Difference-in-Differences (DiD) method. DiD is a panel data statistical technique that calculates the effect of a treatment (explanatory variable) on an outcome (response variable) by comparing the average change over time in the outcome variable for a "treatment group", compared to the average change over time for a "control group". DiD requires data measured at two or more different time periods, viz. before and after "treatment". In our application, the LC variables included in the model allow us not only to identify the before and after periods, but also how intense was the LC process (i.e. the treatment). As in Du et al. (2018), our method can also be viewed as a before-and-after method. However, in our case, the difference between the before and after periods is not the difference of two simple means, but a function of several covariates.

The second issue is spatial dependence. Spatial dependence is known to be particularly severe for small spatial units, such as parishes and municipalities (Da silva et al., 2017). The small size of parishes implies that local factors affecting parishes' production tend to affect production dynamics of neighbouring parishes. Therefore, another weakness of the standard regression analysis in LC evaluation is neglected spatial dependence. To address this issue, we simply enlarge the set of explanatory variables of the model with observed LC variables of neighbouring parishes or locations in the same fashion as a standard spatial lag model (SLX) does.

As it is customary in regional economics, we treat each parish as a production unit. Thus, our observations are not individual farms as in most papers examining the effect of LF on farms' productivity and efficiency (see e.g. Orea et al. 2015), rather aggregate production units comprising many farms. In this sense, we will hereafter assume that our production units "employ" farms (and other *unobserved* inputs captured by the parish-specific effects) to produce dairy and beef products. While an adequate indicator to assess dairy (beef) production is the production of milk (beef) in litres (kilograms) or the farmers' sales in monetary units, there is no data source from which these volumes can be measured directly at parish level. We use parishes' dairy and beef herd sizes as proxies respectively for parishes' dairy and beef production.[2] In this sense, it should be pointed out that most of the literature in agricultural economics shows that the most important input in dairy (beef) production is the dairy (beef) livestock number, and thus both variables are highly correlated.

Although it is possible to split the overall number of farms in a parish into dairy, beef and mix-oriented farms, we cannot allocate the observed dairy and beef livestock to each farm type. This issue forces us to treat each parish as a multi-output production unit. In this sense, we find it very useful the well-known concept of "distance function" in production economics as this primal representation of parishes' production technology allows us to study the effect of the LC processes on both dairy and beef production using a single equation. The basic model with no LC effects can be represented by the equation:

$$lny_{1it} = \alpha_i + \alpha_t + F(x_{it}, y_{2it}/y_{1it}\,, z_{it}) + \varepsilon_{it} \tag{1}$$

where i stands for parish, t stands for periods, y_{1it} and y_{2it} are respectively the number dairy and beef livestock at the parish level, x_{it} is the number of farms located in a parish, z_{it} is a maturity indicator of cattle that has to do with the existence of traditional (e.g. extensive) farms in a particular parish, α_i is a parish-specific fixed effect aiming to capture time-invariant unobserved heterogeneity at the parish level, α_t is a time effect that is included in the model in order to capture the general reduction in farms' activity observed in the last decades, and ε_{it} is an error term measuring random shocks. Finally, in our empirical application we use a Translog (TL) form for the deterministic function $F(\cdot)$. The Translog distance function is a quadratic function in lnx_{it}, $ln(y_{2it}/y_{1it})$ and z_{it} that provides a more general (*flexible*) representation of parishes' production technology (see Diewert, 1971). The estimated elasticities in the TL specification are parish-specific as they are linear functions of lnx_{it}, $ln(y_{2it}/y_{1it})$ and z_{it}.[3]

The basic model in (1) is next extended using a set of variables that try to capture not only the number but also the strength of the LC processes implemented in the parishes included in our sample. The extended specification can be represented by the equation:

$$lny_{1it} = \alpha_i + \alpha_t + F(x_{it}, y_{2it}/y_{1it}\,, z_{it}, LC_{it}) + \varepsilon_{it} \tag{2}$$

where again $F(\cdot)$ is a TL representation of parishes' production technology, and LC_{it} is a vector of three variables, e.g. $LC_{it} = (N_{it}, A_{it}, lnIH_{it})$. N_{it} is a count variable that measures the cumulative number of LC processes in parish i at period t, and A_{it} is the time elapsed since the last LC process. As N_{it}, this variable takes zero values before the first LC process. The third LC-based variable $lnIH_{it}$ is the cumulative public investment (per hectare) involved in LC plans. As the two previous LC indicators, this variable takes zero values before the first LC process because the logged variable is defined as $lnIH_{it} =$

[2] This is not the first time where input and output variables are used for the same purposes. For instance, the relative size of a particular industry is often given by either its value-added share or its labor share (see e.g. Balk, 2016).

[3] We do not take logs in z_{it} as this indicator already takes values between zero and one, and changes in z_{it} can be interpreted as rates of growth.

$ln(IH_{it}+1)$. While N_{it} aims to capture the effect of one or more "representative" LC processes, $lnIH_{it}$ tries to distinguish between weak and intensive LC processes.

It is worth mentioning that the effects of the LC variables are parish-specific as we use a TL representation of parishes' production technology. Although the main focus of this paper is whether LC matters as a whole, the individual coefficients allow us to capture differences among LC processes. The interactions with parishes' characteristics allow us to identify which parishes have benefited the most from the LC processes.

To illustrate how we calculate the effect of LC on parishes' dairy and beef production once (4) has been estimated, let us show the TL formulation of our distance functions with and without LC-based variables. While the TL specification of (1) is

$$lny_{1it} = \Big[\alpha_i + \alpha_t + \beta_x lnx_{it} + \beta_y ln(y_{2it}/y_{1it}) + \beta_z lnz_{it} + \frac{1}{2}\beta_{xx}(lnx_{it})^2 + \frac{1}{2}\beta_{yy}\big(ln(y_{2it}/y_{1it})\big)^2 + \frac{1}{2}\beta_{zz}(lnz_{it})^2 + \beta_{xy} lnx_{it} ln(y_{2it}/y_{1it}) + \beta_{xz} lnx_{it} lnz_{it} + \beta_{yz} ln(y_{2it}/y_{1it}) lnz_{it}\Big] + \varepsilon_{it} \quad (3)$$

the TL specification of (2) can be written as:

$$lny_{1it} = TL(x_{it}, y_{2it}/y_{1it}, z_{it}, \alpha_i, \alpha_t) + \gamma_1 LC_{it} + \frac{1}{2}\gamma_2 LC_{it}^2 + \gamma_x LC_{it} lnx_{it} + \gamma_y LC_{it} ln(y_{2it}/y_{1it}) + \gamma_z LC_{it} lnz_{it} + \varepsilon_{it} \quad (4)$$

where $TL(x_{it}, y_{2it}/y_{1it}, z_{it}, \alpha_i, \alpha_t)$ is the term in brackets in (3).[4] The direct effect of LC on parishes' farm production (hereafter DLCE)[5] is then computed using the following difference of two *conditional* expected productions:

$$DLCE_{it} = E[lny_{1it}|x_{it}, y_{2it}/y_{1it}, z_{it}, LC_{it}, \alpha_i, \alpha_t]_{N_{it}\geq 1} - E[lny_{1it}|x_{it}, y_{2it}/y_{1it}, z_{it}, LC_{it}, \alpha_i, \alpha_t]_{N_{it}=0} \quad (5)$$

This equation measures the effect of LC as the difference between the expected production of a parish that has been involved in a LC process (i.e. when $N_{it} \geq 1$) and the expected production of a *similar* but *hypothetical* parish that has the same explanatory variables (and coefficients) than the above parish but it has not been involved in any LC process (in this case N_{it} should take a zero value). Notice that (5) is conditional on both parish effects, α_i. Therefore, we are controlling for time-invariant differences between the two mentioned parishes. In this sense, our empirical strategy can be viewed as a DiD method. We are also controlling in (5) for differences in the value of α_t before and after the first LC process took place. This prevents us to wrongly attribute to the LC processes the change in parish' production that has to do with exogenous factors that are common to all farms and parishes.

Notice that while the first conditional expectation in (5) is equal to (4) once we drop the noise term, all LC-based variables take the zero value when $N_{it} = 0$, and then the second conditional expectation in (5) is equal to (3) once we drop again the noise term. As both (3) and (4) include $TL(x_{it}, y_{2it}/y_{1it}, z_{it}, \alpha_i, \alpha_t)$, $DLCE_{it}$ in (5) can be alternatively rewritten as follows:

$$DLCE_{it} = \gamma_1 LC_{it} + \frac{1}{2}\gamma_2 LC_{it}^2 + \gamma_x LC_{it} lnx_{it} + \gamma_y LC_{it} ln(y_{2it}/y_{1it}) + \gamma_z LC_{it} lnz_{it} \quad (6)$$

[4] If more than one LC-based variable is used, the equation (4) should be extended with the proper linear and quadratic terms (including interactions) associated to the new LC-based variables.
[5] Why we have added the "direct" label to this effect is explained below in this section.

A common feature of the above two specifications is that they ignore the spatial structure of the data. In other words, (5) and (6) are only capturing a *direct* effect on parishes' production as they ignore that the local LC processes might have also an *indirect* impact on neighbouring parishes' production. To address this issue, we follow the standard SLX model in regional economics and enlarge the set of explanatory variables that appears in (2) with the LC variables of neighbouring parishes:

$$lny_{1it} = \alpha_i + \alpha_t + F(x_{it}, y_{2it}/y_{1it}, z_{it}, LC_{it}) + \lambda W_i LC_t + \varepsilon_{it} \tag{7}$$

where LC_t is a vector of $Px1$ LC-based variables, P is the number of cross-section parishes in our sample, W_i is a known $1xP$ spatial weight vector with elements that are equal to zero if a particular parish j is not a neighbour of parish i and equal to one if the two parishes are neighbours or adjacent. Equation (7) is a model that now includes a set of spatially lagged variables, i.e. $W_i LC_t$.[6] Therefore, (7) resembles a conventional spatial SLX model, where the term λ is a coefficient that measures the effect of neighbours' LC processes on the production of a parish.[7] Once λ has been estimated, we can measure the *indirect* or *spatial* effect of neighbours' LC processes as follows:

$$ILCE_{it} = \lambda W_i LC_t \tag{8}$$

Finally, the *total* effect of LC on parishes' farm production is then simply computed by adding both direct and indirect effects:

$$LCE_{it} = DLCE_{it} + ILCE_{it} \tag{9}$$

Auxiliary regressions

Our previous empirical models aim to measure the economic impact of LC processes at the parish scale, conditional on the number of farms. To get an overall view of the subject we need to estimate the effect of our LC-based variables on the number of farms. In order to take into account the different composition of the farms located in each parish, we split the sample into dairy, beef and mix-oriented parishes and propose estimating the following auxiliary regression for each type of parish:

$$lnx_{it} = \alpha_{ji} + \alpha_{jt} + \delta_j LC_{it} + \tau_j W_i LC_t + v_{jit} \tag{10}$$

where j stands for parish type (j=dairy, beef and mix-oriented), x_{it} is the number of farms, α_{ji} and α_{jt} are two fixed effects aiming to capture the effect of parish-specific (but time-invariant) and time-specific (but common to all parishes) unobserved variables on x_{it}, and v_{jit} is an error term measuring random shocks. In the same fashion as LCE_{it}, the effect of LC on parishes' farm numbers is computed as follows once (10) has been estimated:

$$XLCE_{it} = \delta_j LC_{it} + \tau_j W_i LC_t \tag{11}$$

Overall effects

In order to get an overall effect of LC on parishes' production, we need to combine somehow the conditional LCE_{it} effect (i.e. the effect of LC on lny_{1it} and lny_{2it} given x_{it}) and $XLCE_{it}$ (i.e. the effect of LC on x_{it}). A very simple method to achieve this objective is estimating a distance function without x_{it}, and use the parameter estimates of

[6] Notice again that $W_i LC_t$ is a vector of three LC-based variables, e.g. $W_i LC_t = (W_i N_t, W_i A_t, W_i lnIH_t)$.

[7] Halleck-Vega and Elhors (2015) provide a comprehensive overview of the strengths and weaknesses of different spatial econometric model specifications in terms of spillover effects. Based on their overview, they advocate taking the SLX model as point of departure in case a well-founded theory indicating which model is most appropriate is lacking.

this unconditional model to compute (6) and (9). This model is misspecified because a significant explanatory variable has been dropped. Indeed, if we omit x_{it} (and its square and interactions) from equation (4), the estimated coefficients associated to the LC-based variables will be (on purpose) biased because they will be capturing both the conditional effect on parishes' production and the effect via a reduction (increase) in the number of farms, an omitted variable in this specification.[8] As Orea (2008), we take advantage of this misspecification to combine both effects.

3. Sample and data

The data used in our study comes from two complementary sources and has allowed us to have a panel of parishes from 2001 to 2017. On the one hand, SADEI has provided us with annual information at the parish level that contains the following variables: population, parish's total land area, number of bovine farms, total bovine herd (both beef and dairy), and livestock units (see SADEI, 2011).[9] On the other hand, the Principality of Asturias has provided us with information on the processes of LC carried out from 1963 to the present, with data about the parishes and municipalities affected, the treated hectares, the starting and ending plots number, the date of taking possession of the new plots, the volume of public investment in the development and implementation of the LC processes, etc.

The variables used to estimate our distance functions are defined as follows. The two outputs of the distance functions (3) and (4) are y_{1it} and y_{2it} , i.e. the total number of dairy and beef bovine animals respectively. The main input of the parishes' distance function is the total number of bovine farms, x_{it}. This variable includes dairy, beef and mix-oriented farms. As mentioned in Section 2, it is not possible to allocate the observed dairy and beef livestock to each farm type because all of them uses dairy and beef cows, but in different proportions. In particular, the farms are classified as dairy farms when the dairy livestock units (LU) only exceed 2/3 of the total livestock units.[10] Therefore, beef livestock units in some of these farms might represent up to 33 percent of the total LU. Similar comments deserve the other two categories.[11]

To distinguish between traditional (extensive) and non-traditional (intensive) farms in each parish, we have included in our distance function the ratio livestock units to total bovine herd, z_{it}. Total bovine herd is the sum of dairy livestock and beef livestock. The z-ratio is a maturity indicator of farms' cattle. z_{it} is less than unity since the total of the bovine herd includes all bovine animals whether they are adult cows, heifers, and young calves. Adult cows count as one livestock unit, while younger animals count less than one livestock unit. A ratio equal to 1 would imply that all the bovine animals would be adult cows. The higher the value of the ratio, the less weight the younger animals have

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[8] A more comprehensive method to combine both effects relies on the following differential equation that requires computing the elasticity of lny_{1it} with respect to lnx_{it}:

$$\frac{dlny_{1it}}{dLC_{it}} = \frac{\partial lny_{1it}}{\partial LC_{it}} + \frac{\partial lny_{1it}}{\partial lnx_{it}} \cdot \frac{\partial lnx_{it}}{\partial LC_{it}}$$

[9] See http://www.sadei.es/datos/sad/vacas/vacas.aspx

[10] The livestock unit sometimes abbreviated as LU (or LSU) "is a reference unit which facilitates the aggregation of livestock from various groups of age as per convention, via the use of specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal". This definition was obtained from Eurostat website (see https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Livestock_unit_(LSU)).

[11] While the farms are classified as beef farms when the beef livestock units exceed 2/3 of the total LU, the mix-oriented farms are those farms with beef and dairy livestock units less than 2/3 of the total LU.

in the herd of cattle (calves and heifers). It is worth mentioning that z_{it} can also be viewed as an indicator of the traditional (extensive) character of livestock in each parish. In the case of dairy farms, the lower the z-ratio, the more weight the heifers have. This reflects that the farms require a high rate of annual replacement of cows because dairy cows of high production usually have a shorter productive life. Therefore, in the case of milk orientation at lower value of z-ratio, greater intensification of productive activity (cows with higher production, with more feed consumption per cow, etc.). On the other hand, in the case of beef farms, the lower the z-ratio the more weight the calves have (breeding and baiting). The higher the value of the z ratio, the lower the weight of the calves in the cattle. This could indicate that the meat holdings have few calves in the process of bait, and this would be the case of farms that decide to sell the calves after a few months of life to be fattened in other more professional farms (feedlots) outside de parish.

The effect of LC on parishes' production is measured using three variables capturing the quantity and the intensity of the LC processes. The first LC variable is the cumulative number of LC processes, N_{it}. This variable does not necessary begin with a zero value in 2001 because it also considers the LC processes that were implemented in the 90s. N_{it}(and its square) is *originally* included in the model in order to examine if the LC processes have had a positive but decreasing effect on parishes' dairy and beef production. As this effect is conditional on the number of farms, it can alternatively be interpreted as an effect on farms' average size.[12] The effect of N_{it} is a bit uncertain in practice because it might be also controlling for the discontinuity of the other two LC variables. The second LC-based variable is the time elapsed since the last LC process, A_{it}. This variable is included in the model due to a new LC process might not have an immediate effect on parishes' production (and average farms' size) but a delayed impact.[13] Notice as well that the time trend measuring the time elapsed since the last LC process is reset and starts up again taking the unity value each time a new LC process takes place. Thus, A_{it} exhibits a discontinuity each time N_{it} increases. The third LC-based variable is the natural logarithm of the cumulative public investment (per hectare) involved in LC plans, $lnIH_{it}$. While N_{it} simply measures the quantity of LC processes, $lnIH_{it}$ measures their intensity. This variable begins to take (high) positive values when we move from zero processes to unity. Thus, $lnIH_{it}$ exhibits a discontinuity when $N_{it} = 1$ the first time.

Table 1 shows the descriptive statistics of 292 parishes over the period 2001-2017. The total sample size is 4,964 observations. 1,056 observations have been involved in one or more LC processes. As all LC variables in a parish take a zero value before the first LC process is implemented, the descriptive statistics of these three variables are computed using 1,056 observations. For comparison grounds, we also provide the descriptive statistics of spatial lags of these LC variables for 1,056 observations.

[Insert Table 1 here]

Our output distance functions are conditional on the number of farms and hence the estimated parameters of the time dummy variables measure here the "natural" tendency of parishes' average farm size over time. Similar comments deserve the parameters of the time dummy variables of our auxiliary regressions. As the parameters of the time dummy variables are not shown in next section, we provide in Figure 4 the

[12] It also might capture an effect on farms' structure if it is interacted with y_{2it}/y_{1it}.

[13] Crecente (2002) concludes that data from two consecutive years are insufficient to evaluate properly the effects of LC. In this sense, for a project completed in period t, Du et al. (2018) consider the period $(t-6, t-1)$ as before consolidation, and $(t+1, t+6)$ as after consolidation.

annual parish average farm size (measured as average cows per farm) and farm figure. This figure shows a persistent decline in the number of farms over the last 17 years. This evolution just captures the increasingly cessation of livestock activity in the Asturian rural areas.[14] This figure also shows that the above restructuration of livestock production has favoured concentration and intensification of production on larger farms.

[Insert Figure 4 here]

4. Results.

4.1. Conditional LC effects

The parameter estimates of four different specifications of the output distance functions in (4) are shown in Table 2. First, we provide in column (1) the Translog function with a linear function of LC variables capturing direct effects on parishes' production. In column (2) we extend the model including interactions between LC indicators. Here we only consider the number of farms as an input to "produce" milk, the beef-to-dairy livestock ratio to control for substitution effects between dairy and beef products, and z_{it} (or z-ratio) as control variable. In addition, we introduce the three variables capturing the quantity and the intensity of the LC processes. The third model allows examining non-neutral effects of the LC variables as they are interacted with the production determinants of the distance functions. These interactions let us to know whether e.g. the effect of the LC processes is more intensive in large parishes (i.e. with many farms), in parishes more oriented to dairy production or in parishes with more traditional farms. The last model adds spatial lags of the LC variables in order to capture indirect effects from neighbouring parishes. The explanatory variables have been divided by the geometric mean of the parishes involved in one or more LC processes. This transformation has no effect on the estimation but allows the first-order coefficients to be interpreted as elasticities for a "representative" parish involved in LC processes. The F statistic of join significance in Table 2 indicate that all production parameters (including time dummies) are significant. The abovementioned specifications have been estimated using the fixed effects estimator in order to control for parish-specific but time-invariant unobserved variables for the researcher. The performed F tests also reject that all $\alpha_i = 0$, indicating that there are significant differences in unobserved environmental conditions among parishes. The estimated fixed-effects (not shown) not only capture other relevant inputs for farms' production but also other geographical and socio-economic variables that condition farms' size.

[Insert Table 2 here]

The similarities in the coefficients between the different specifications confirm the robustness of our specifications. As expected, we find a negative and significant relationship between parishes' beef and dairy production, conditional on the number of farms. The estimated elasticity is on average less than unity in absolute terms, indicating that parishes "adjust" dairy cattle less than beef cattle. On the other hand, we find a positive effect of the number of farms on dairy and beef livestock. This is also an expected result. Again the estimated elasticity is on average less than unity, indicating the existence of decreasing returns to scale at parish level. In other words, parishes with more farms tend to have smaller farms in terms of beef and dairy cattle. Furthermore, the negative coefficient associated to z_{it} implies that more extensive (and traditional) farms tend to be

[14] Due to this cessation, the number of farms and the livestock numbers are zero at the end of the sample period in a few parishes.

smaller as they on average use less beef and dairy cows than more intensive farms. The quadratic and interaction terms are also very similar in all specifications of the distance function (4). Except for z_{it}, the quadratic terms are negative. The negative coefficient for the beef herd indicates that the underlying production possibility curve is concave to the origin as it is customary in the economic production theory. The effect of the number of farms on dairy (and beef) herd adopts a form of inverted U due to the first-order effect is positive and the quadratic term is negative. The opposite result is observed for z_{it}. Finally, it is worth mentioning that the parameters of the interaction terms are significant but with different signs. Therefore, the above-mentioned effects are sometimes attenuated (if the sign is negative) or intensified (positive sign) by other production determinants.

We have also included three different LC indicators in our models to measure the effect of LC processes on parishes' dairy and beef production. In particular, we consider the number of processes, an indicator that collects the time elapsed between processes, and the investment per hectare measuring the intensity of the LC processes. Although we are more interested in overall effects than in individual effects because each LC process is a complex phenomenon, we find that the first-order coefficient of N_{it} is not significant in most specifications. Moreover, it has a negative coefficient when the model does not include second-order coefficients. As anticipated before, the discontinuity of the other two LC variables might explain counterintuitive or non-significant results associated to this variable when estimating both our distance functions or auxiliary regressions. The first order coefficient of A_{it} is positive and significant. This result seems to indicate that, on average, the LC processes do not have an immediate effect on Asturias parishes' production (and on average farm size) but a delayed impact. However, the quadratic coefficient of A_{it} is negative. Therefore, there is an inverted U-shaped effect associated to the time elapsed since the last LC process, indicating that the effect tends to vanish after several years. In contrast, we find a proper U-shaped effect associated to $lnIH_{it}$. The investment tends to have a negative effect on parishes' livestock production for small investments levels, but positive when the investment involved in the LC process is sufficiently large. However, our LCE figures shown later in this section seems to indicate that this quadratic effect is not enough to compensate the first one. It is also worth noting that the interactions between the LC indicators are not statistically significant in our more comprehensive models.

Models 3 and 4 include interactions between our LC indicators and the production determinants of the distance function. The coefficient of $lnx_{it}N_{it}$ is always positive and statistically significant, indicating that adding new LC processes is more effective in parishes with many farms. This result indicates the existence of some synergies between LC processes when the number of farms located in such a parish is large. Therefore, this finding seems to suggest policy makers to accumulate LC processes in large parishes rather than in small parishes with few farms. Another statistically significant and negative interaction is $ln(y_{2it}/y_{1it})A_{it}$. This coefficient indicates that the effect of the LC processes is less intensive in beef-oriented parishes than in parishes more oriented to milk production. As most of the dairy livestock is in coastal municipalities, the effects of LC on livestock production will be larger in littoral areas. Another remarkable result is the positive and statistically significant coefficient of $z_{it}lnIH_{it}$. This coefficient indicates that the public investments in infrastructures tend to have a larger (positive) effect in parishes where the local farms use more traditional systems of livestock production. The negative coefficient of $z_{it}A_{it}$ suggests, however, that this effect is less intense over time.

A common feature of the first three models in Table 2 is that they ignore the spatial structure of the data. In other words, they only capture *direct* effects on parishes' production. In order to capture *indirect* effects associated to LC processes implemented in neighbouring parishes, Model 4 enlarges the set of explanatory variables with spatial lags of LC variables. We observe that the spatial spillover (or between-parishes) LC effects are as relevant as the internal (or within-parishes) LC effects, thereby confirming the importance of considering the notion of spatial interactions in studies that rely on very disaggregated spatial information. The positive and significant coefficients of the average number of neighbouring LC processes and their age confirm the existence of positive spillovers coming from the neighbouring parishes. Therefore, the quantity of LC processes in neighbouring parishes affect positively local livestock production. On the contrary, we observe negative spillover effects in terms of investment per hectare, which may arise through competition in financial support between parishes. They are indicative of backwash Myrdal´s effects (Gude et al., 2018). However, our LCE figures shown later in this section seems to indicate that such an effect is not enough to compensate the positive effects associated to the number of neighbouring LC processes and their age. In spite of the results obtained in relation to the investment in LC processes, the public investment effort might have positive effects on other variables not considered in our model, such as the satisfaction of the inhabitants of rural areas with the improvements made on roads and access to plots and villages.

In summary, as in Deininger and Xia (2016), we find significant spillover effects in Asturias as the effect of a localized LC project expands beyond the area in which such measure has been implemented. This finding first indicates that the LC effects are likely underestimated if we only examine the local economic impacts of such processes. Another important implication of the above result is that Asturian policy makers should likely initiate *wide* LC processes involving simultaneously several parishes if they aim to promote livestock (or economic) activity in a particular rural area, rather than initiating *dispersed* or poorly coordinated LC processes.

We next proceed to calculate the effect of LC on parishes' dairy and beef production using the parameter estimates of Model 4 in Table 2, our more comprehensive model. While the *direct* effect of each parish is computed using (6), the *indirect* (spatial) impact is computed using (8). The *total* effect of LC on parishes' livestock production is then simply computed by adding both parish-specific direct and indirect effects, i.e. using (9). Figure 5 presents the distribution of the total effect as well as its disaggregation into direct and indirect effects, understood as the effects from LC processes performed inside the parishes and those from the surrounding ones. They all have been computed using the complete sample of parishes. We can conclude from these distributions that the LC effects are generally positive. The average total effect from the LC processes is around 10.8 percent. Its decomposition into direct and indirect effect is on average positive as well: 7.1% and 3.8% respectively. As is shown in Table 1, the average age of the processes is around 8 years. This implies an annual total effect of 1.4%, which is divided into a direct annual effect of 0.9% and an indirect effect of 0.5% per year. The positive (and relative larger) magnitude of the direct effect corroborates the previous literature that finds a positive contribution of LC processes on rural economic activity (see, e.g. Crecente et al. 2002, for Galician parishes).[15] The indirect effect hence accounts for around 40% of the total impact, corroborating, in line with Deininger and Xia (2016), the importance for accounting for both types of effects, and particularly the spatial LC spillover effects generated in neighbouring parishes.

[15] It is worth highlighting that the distribution of the direct effect is quite disperse, indicating that our DLCE estimates are rather inconclusive due to the presence of large negative and positive point estimates.

[Insert Figure 5 here]

The previous results can be interpreted as "average effects" as they all have been computed using the whole set of parishes in our sample. We differentiate between parishes in Figure 6 according to several criteria. Our criteria have to do with the number of LC processes (one vs two or more), the time elapsed from the previous process (recent or distant)[16], the localization of parishes (inland vs coast), the intensity of the LC processes (small vs large investment)[17], the specialization of the farms located in parishes (beef, dairy and mix-oriented), and the use of traditional system of livestock production (traditional vs non-traditional) [18]. This allows us to get a more accurate assessment of the magnitude of the LC impact across different types of parishes.

[Insert Figure 6 here]

We obtain interesting findings once we split the sample into several groups. For instance, we find that the positive effect of LC is as expected more intensive in parishes that either have experimented two or more LC processes or the last process finished one decade ago or more. The later result thus confirms the Crecente et al. (2002, p. 142) findings in the sense that a two-year period is not enough to capture the final LC effects. The third distribution considers whether the parishes are in inland or coastal municipalities. We find that the coastal parishes are the most benefited by the LC processes. As most of the dairy livestock is located in coastal municipalities, this result is confirmed by the next distribution that shows the different effects between parishes with a greater percentage of farms specialized in beef, milk or both types of livestock production. This distribution suggests the existence of a positive effect in parishes mainly specialized in dairy farms, while those specialized in beef herd present a negative effect. Interestingly, LC processes are mainly observed in those parishes where the dairy-oriented farms predominate. Therefore, it seems that the Asturian policy makers have already considered that the effect is larger in these parishes than in beef-oriented parishes. The fifth distribution has to do with the intensity of the LC processes. We find here that a greater investment does not necessarily imply more livestock production at parish level. Finally, the sixth distribution distinguishes the effect of LC processes between parishes with extensive farms using traditional systems of livestock production, and parishes with more intensive farms. As previous studies, we find that the effect is more relevant for extensive farms. For instance, Orea et al. (2015) also concluded that the LC processes would particularly improve extensive farms' profits rather than the returns of the intensive farms.

In general, these findings corroborate previous researches focused on rural areas at spatial level (see, e.g. Crecente et al., 2002 in Spain, Du et al., 2018 and Zhou et al., 2019 for China or Dudzińska et al., 2018 in Poland) as we also find that the LC processes are key policies to promote the socioeconomic conditions in rural areas.

4.2. Unconditional LC effects

As previously discussed, LC processes might affect Asturian parishes' livestock production via the number of farms. To explore this possibility, we have estimated a set of *auxiliary regressions* that include both internal LC indicators and their spatial lags as

[16] The *distant* group includes parishes where the last LC process finished one decade ago or more. Otherwise, it is included in the *recent* group.

[17] The *small* (*large*) investment group includes parishes with less (more) investment per hectare than the sample average.

[18] The *traditional* (*non-traditional*) group includes parishes with more (less) z-ratio than the sample average.

explanatory variables of the number of farms. The parameter estimates of these regressions are presented in Table 3. In order to take into account the different composition of the farms located in each parish, we have split the sample into dairy, beef and mix-oriented parishes. Once again, the regressions are performed including time dummies and parish-specific effects. The F-test corroborates the joint significance of both the explanatory variables and the fixed effects.

If we use the complete sample of observation, we do not get significant direct effects of the LC processes on the number of farms (only a very slightly negative effect from the number of projects). Nevertheless, these results confirming the positive spillovers coming from the LC processes in adjacent parishes. Therefore, the most remarkably indirect effect is the positive one emerging from the number of processes in surrounding areas. So, we can conclude in this sense that the increase in the number of farms has been mainly incentivized for the LC processes carried out in other but nearby parishes.

In order to obtain a more precise measure of this impact, the next columns in Table 3 present the same specification for beef, dairy and mix-oriented parishes respectively. It is worth noting that beef-oriented parishes represent 48% of the total sample of parishes, while mix and dairy-oriented parishes represent 38% and 14%, respectively. Although we are again more interested in overall effects than in individual effects, the group-specific estimates show that a positive farm effect of both the number and age of the LC processes emerges in mix production-oriented parishes. Distant LC processes also have a significant and positive effect on the farms of beef-oriented parishes. In contrast, the number of LC processes affect negatively farms figures in both beef and dairy-oriented parishes. It should also be highlighted that the indirect or spatial spillover effects are quite significant. Moreover, we next show that the indirect effect is even more relevant than the direct effect.

[Insert Table 3 here]

The last column in Table 4 provides the direct and indirect effects of LC on parishes' farm numbers that have been computed using (11) and the parameter estimates in Table 3. This column shows that the indirect effect of LC on farm numbers is on average positive (5.2%) for the whole set of parishes that were involved in LC processes. This favourable effect is partially offset by the negative direct effect (-3.4%). The total effect is thus slightly positive (1.7%). This decomposition changes when we have a look at the three groups of parishes in terms of specialization. Indeed, while the direct effect on farm numbers is negative (negligible) for beef-oriented (mix-oriented) parishes, the LC processes have clearly stimulated the creation of new dairy farms. Notice that a positive effect here does not imply that the number of farms increases over time due to the increasingly negative coefficients of the time dummies included in our auxiliary regression. They rather indicate that the decline in the number of farms is attenuated by the LC processes.

[Insert Table 4 here]

Table 4 also provides the overall and conditional effects of LC on parishes' livestock production. We have used the parameter estimates of an unconditional distance function model to get overall effects on parishes' livestock production. This model (not shown) captures both the conditional LC effect examined in the previous subsection as well as the LC effect via a reduction (increase) in the number of farms. Conditional on the number of farms, as shown in Subsection 4.1, this table provides positive direct and indirect LC effects on parishes' livestock production for the whole set of parishes involved in LC processes (7.1% and 3.7% respectively). Again, this decomposition changes when we examine the three groups of parishes in terms of specialization. Indeed, while all conditional effects are positive for dairy and mix-oriented parishes (i.e. the total effects are 22.5% and 15.7% respectively), both total and direct conditional effects for the beef-oriented parishes are negative (-5.9% and -8.9% respectively). Notice that the negative effects do not imply that beef-oriented farm size decreases over time due to the increasingly positive coefficients of the time dummies included in our distance function. They rather indicate that the increase in size of these farms is less than in dairy and mix-oriented farms.

Regarding the overall (unconditional) effect of LC, we find that parishes' livestock production increases about 16.3%, mainly thanks to the positive indirect effects associated to both farms' size and numbers. This result represents annual increases of 2.1% in parishes' livestock production. To test the stability of this result, we split the sample of parishes involved in LC processes into beef, dairy and mix-oriented parishes. As previously discussed, beef-oriented parishes are less benefited from LC. If we divide the cumulative total effect for this group (-5.5%) by the average age of the processes average, we get an annual deterioration in parishes' beef production of 0.7% due to the negative direct effects associated to both farms' size and numbers. In this case, the indirect effects offset partially but not totally the adverse direct effect on parishes' beef production. The unconditional results for dairy and mix-oriented parishes change considerably as they all are positive, with cumulative increases of 30% and 23% respectively, which in turn represent annual increases of 3.1% and 3.3% in parishes' livestock production.

The abovementioned effects can be considered as a lower bound of the overall effect attributed to LC processes because we still have not examine the indirect effects on parishes that have never implemented any LC process. In this sense, we have found a slightly less but positive indirect effects for these parishes. For instance, the computed unconditional indirect effects attributed to neighbouring LC process are on average 8.2%. The effect via number of farms and the conditional effect on farms size are also remarkable, about 3.5% and 2,5% respectively.

5. Conclusions

The objective of this research is to evaluate the impact of the land consolidation (LC) processes that have taken place in Asturias during the period 2001-2017. During the last decades, and particularly during the period under study, Asturias has received European funds to promote concentration processes for three reasons. First, the land has traditionally been fragmented in Asturias. Second, previous research often has found that the LC processes are important tools to improve the economic activity in rural areas, increase farmer income, and stabilize their population. Finally, recent regulation in Asturias has contribute to encourage those processes.

We first base our estimation in a production approach using parishes' dairy and beef herd as proxies for livestock production and several LC-based variables that aim to capture the quantity and intensity of the LC processes implemented in each parish. In addition, we analyse the effect of LC-based variables on the number of farms using auxiliary regressions. The overall effect is then computed combining both effects. Our main contributions to this literature have to do with the panel data techniques used to estimate all models, and the spatial interdependence that has been incorporated into our analysis by adding the LC indicators of neighbouring parishes. This last feature allows us to decompose the total effects attributed to LC into direct and indirect effects.

In summary, we find an annual effect of about 2.1% on parishes' livestock production attributed to LC processes in Asturias, which has mainly benefited parishes with dairy and mix-oriented farms. These improvements can be attributed to different sources. While the positive effect in dairy-oriented parishes is mainly due to the direct effect generated by internal LC processes, the livestock production gains in the mix-oriented parishes are caused by indirect or spatial effects generated in neighbouring parishes. It should also be highlighted that the 2.1% increase above is only a lower bound as it ignores the non-negligible indirect effects on parishes that have never implemented any LC process. Although the contribution of LC processes to parishes livestock production is positive, we find that their impact is not homogenous. For instance, the positive effect of LC is more intensive in parishes that either have experimented two or more LC processes or the last process finished one decade ago or more. The effect is also larger in coastal parishes and in parishes with dairy farms. In addition, we find that the LC effect is more relevant in parishes with more extensive and traditional farms.

Overall these results advocate using spatial econometrics techniques in the empirical examinations of economic effects attributed to LC processes. They also advocate using coordinated LC measures by the regional governments in order to take full advantage of this important policy. Policy makers should also be aware that the impact of their LC processes might depend on parishes characteristics and that the expected effects might be underestimated if the spatial spillover effects of such measures are ignored.

References

Ali, D., Deininger, K., Harris, A. (2019): “Does Large Farm Establishment Create Benefits for Neighbouring Smallholders? Evidence from Ethiopia”, *Land Economics*, 95:71-90.

Álvarez-Ayuso, I., Condeço-Melhorado, A.M., Gutiérrez, J., Zofío, J.L. (2016): “Integrating Network Analysis with the Production Function Approach to Study the Spillover Effects of Transport Infrastructure”, *Regional Studies*, 50:6, 996-1015, DOI: 10.1080/00343404.2014.953472

Balk, B. (2016): “The dynamics of productivity change: A review of the bottom-up approach”. In Productivity and efficiency analysis., W. Greene, L. Khalaf, R. Sickles, M. Veall, and M-C. Voia (Eds.), Chapter 2, 15-49, Springer, Cham.

Burger, A. (2001): “Agricultural development and land concentration in a central European country: a case study of Hungary”, *Land Use Policy*, 18:259–268.

Coelho, J., Pinto, P.A., Silva, L.M. (2001): “A systems approach for the estimation of the effects of land consolidation projects (LCPs): a model and its application”, *Agricultural Systems*, 68:179–195.

Colombo, S., Perujo-Villanueva, M. (2019): “A practical method for the ex-ante evaluation of land consolidation initiatives: Fully connected parcels with the same value”, *Land Use Policy*, 81:463–471.

Crecente, R., Alvarez, C., Fra, U. (2002): “Economic, social and environmental impact of land consolidation in Galicia”, *Land Use Policy*, 19:135–147.

Da Silva, F.C., Diego, Paul Elhorst, J.P., da Mota, R. (2017): "Urban and rural population growth in a spatial panel of municipalities", *Regional Studies*, 51(6): 894-908.

Deininger, K., Xia, F. (2016): “Quantifying Spillover Effects from Large Land-based Investment: The Case of Mozambique”, *World Development*, 87:227-241.

del Corral, J., Perez, J.A., Roibas, D. (2011): “The impact of land fragmentation on milk production”, *Journal of Dairy Science*, 94:517–525.

Demetriou, D. (2018): “Automating the land valuation process carried out in land consolidation Schemes”, *Land Use Policy*, 75, 21–32.

Diewert, W. E. (1971) "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function", *Journal of Political Economy*, 79, 461-507.

Du, X., Zhanga, X., Jinb, X. (2018): “Assessing the effectiveness of land consolidation for improving agricultural productivity in China”, *Land Use Policy*, 70:360-367.

Dudzińska, M., Bacior, S., Prusc, B. (2018): “Considering the level of socio-economic development of rural areas in the context of infrastructural and traditional consolidations in Poland”, *Land Use Policy*, 79:759–773.

Guo, B., Jin, X., Yang, X., Guan, X., Lin, Y., Zhou, Y. (2015): “Determining the effects of land consolidation on the multifunctionlity of the cropland production system in China using a SPA-fuzzy assessment model”, *European Journal of Agronomy*, 63:12–26.

Gude, A., Alvarez, I., Orea, L. (2018): “Heterogeneous spillovers among Spanish provinces: a generalized spatial stochastic frontier model”, *Journal of Productivity Analysis*, 50: 155-173.

Halleck Vega, S., Elhorst, J. P. (2015): “The SLX model”, *Journal of Regional Science*, 55(3): 339-363.

Hartvigsen, M. (2014): “Land reform and land fragmentation in Central and Eastern Europe”, *Land Use Policy*, 36:330–341.

Hiironen, J., Riekkinen, K. (2016): “Agricultural impacts and profitability of land consolidations”, *Land Use Policy*, 55:309-317.

Janus, J., Markuszewska, I. (2019): “Forty years later: Assessment of the long-lasting effectiveness of land consolidation projects”, *Land Use Policy*, 83:22–31.

Jiang, G., Zhang, R., Ma, W., Zhou, D. Wang, X., He, X. (2017): “Cultivated land productivity potential improvement in land consolidation schemes in Shenyang, China: assessment and policy implications”, *Land Use Policy*, 68:80–88.

Jin, X., Shao, Y., Zhang, Z., Resler, L.M, Campbell, J.B., Chen, G., Zhou, Y. (2017): “The evaluation of land consolidation policy in improving agricultural productivity in China”, Scientific Reports, 7, Article number: 2792, www.nature.com

Lerman, Z., Cimpoieş, D. (2006): “Land Consolidation as a Factor for Rural Development in Moldova”, *Europe-Asia Studies*, 58(3):439-455.

Li, Y., Wu, W., Liu, Y. (2018): “Land consolidation for rural sustainability in China: Practical reflections and policy implications”, *Land Use Policy*, 74:137–141.

Lisec, A., Primozic, T., Ferlan, M., Sumrada, R., Drobne, S. (2014): “Land owners’ perception of land consolidation and their satisfaction with the results – Slovenian experiences”, *Land Use Policy*, 38:550–563.

Luo, W., Timothy, D.J. (2017): “An assessment of farmers’ satisfaction with land consolidation performance in China”, *Land Use Policy*, 61:501-510.

Manjunatha, A.V., Anik, A.R., Speelmand, S., Nuppenaua, E.A. (2013): “Impact of land fragmentation, farm size, land ownership and crop diversity on profit and efficiency of irrigated farms in India”, *Land Use Policy*, 31:397-405.

Miranda, D., Crecente, R., Alvarez, M.F (2006): “Land consolidation in inland rural Galicia, NW Spain, since 1950: An example of the formulation and use of questions, criteria and indicators for evaluation of rural development policies”, *Land Use Policy*, 23:511-520.Nilsson, P. (2018): “The Role of Land Use Consolidation in Improving Crop Yields among Farm Households in Rwanda”, *The Journal of Development Studies*, DOI: 10.1080/00220388.2018.1520217.

Orea, L. (2010): “The effect of legal barriers to entry in the Spanish retail market: a local market approach”, *Hacienda Pública Española*, 193(2), 49-74.

Orea, L., Pérez-Méndez, J.A., Roibás, D. (2015): “Evaluating the double effect of land fragmentation on technology choice and dairy farm productivity: A latent class model approach”, *Land Use Policy*, 45:189-198

Rahman, S., Rahman, M. (2008): “Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh”, *Land Use Policy*, 26:95–103.

Shi, Y., Cao, X., Fu, D., Wang, Y. (2018): "Comprehensive Value Discovery of Land Consolidation Projects: An Empirical Analysis of Shanghai, China", *Sustainability*, 10(6), 2039.

Vitikainen, A. (2004): “An Overview of Land Consolidation in Europe”, *Nordic Journal of Surveying and Real Estate Research*, 1: 25-44.

Wan, G. H., Cheng, E. (2001): “Effects of land fragmentation and returns to scale in the Chinese farming sector”, *Applied Economics,* 33:183–194.

Wang, J., Yan, S., Guo, Y., Li, J., Sun, G. (2015): “The effects of land consolidation on the ecological connectivity based on ecosystem service value: A case study of Da’an land consolidation project in Jilin province”, *Journal fo Geographical Sciences*, 25(5):603-616.

Wu, Z., Liu, M., Davis, J. (2005): “Land consolidation and productivity in Chinese household crop production”, *China Economic Review*, 16:28-49.

Yu, G., Feng, J., Che, Y., Lin, X., Hu, L., Yang, S. (2010): “The identification and assessment of ecological risks for land consolidation based on the anticipation of ecosystem stabilization: a case study in Hubei Province, China”, *Land Use Policy,* 27:293–303.

Zeng, S., Zhu, F., Chen, F., Yu, M., Zhang, S., Yang, Y. (2018): “Assessing the Impacts of Land Consolidation on Agricultural Technical Efficiency of Producers: A Survey from Jiangsu Province, China”, *Sustainability*, 10(7): 2490.

Zhang, Z., Zhao, W., Gu, X. (2014): “Changes resulting from a land consolidation project (LCP) and its resource–environment effects: a case study in Tianmen City of Hubei Province, China”, *Land Use Policy,* 40:74–82.

Zhang, Q., Zhang, T. (2018): “Land Consolidation Design Based on an Evaluation of Ecological Sensitivity”, *Sustainability*, 10(10): 3736.

Zhou, Y, Guoc, L., Liu, Y. (2019): “Land consolidation boosting poverty alleviation in China: Theory and practice*”, Land Use Policy,* 82:339–348.

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Table 1. Descriptive Statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
y_1	Dairy livestock	4,964	283.6	454.3	0	2779
y_2	Beef livestock	4,964	333.9	338.0	0	3317
x	Dairy, beef and mix-oriented farms	4,964	23.3	18.4	0	153
z	Livestock units / (Total bovine herd+1)	4,912	0.71	0.10	0	0.89
D_{beef}	Dummy variable for Beef-oriented parishes	4,964	0.48	0.50	0	1
D_{milk}	Dummy variable for Dairy-oriented parishes	4,964	0.14	0.35	0	1
D_{mix}	Dummy variable for Mix-oriented parishes	4,964	0.38	0.49	0	1
N	Number of LC processes	1,056	1.46	0.78	1	5
A	Time elapsed since last LC process	1,056	7.76	5.77	1	27
IH	Public investment per hectare	1,056	1,595	1,200	0	6,170
WN	Neighbours' average number of LC processes	1,056	0.73	0.65	0	3.8
WA	Neighbours' average time elapsed since last LC process	1,056	3.11	2.51	0	14
WIH	Neighbours' average public investment per hectare	1,056	725.7	778.4	0	4,293

Table 2. Parameter estimates of the distance functions

	Model 1			Model 2			Model 3			Model 4		
Variable	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.
$\ln y_2$	-0.721	***	0.009	-0.721	***	0.009	-0.749	***	0.011	-0.748	***	0.011
$\ln x$	0.826	***	0.022	0.830	***	0.022	0.872	***	0.031	0.876	***	0.031
z	-0.933	***	0.228	-0.953	***	0.228	-0.651	*	0.385	-0.531		0.388
$1/2(\ln y_2)^2$	-0.062	***	0.003	-0.062	***	0.003	-0.061	***	0.003	-0.061	***	0.003
$1/2(\ln x)^2$	-0.166	***	0.018	-0.161	***	0.018	-0.159	***	0.018	-0.156	***	0.018
$1/2z^2$	4.003	***	0.987	4.089	***	0.988	4.543	***	0.984	4.482	***	0.984
$\ln y_2 \cdot \ln x$	-0.066	***	0.005	-0.068	***	0.005	-0.074	***	0.005	-0.075	***	0.005
$\ln y_2 \cdot z$	0.489	***	0.049	0.490	***	0.049	0.426	***	0.049	0.425	***	0.049
$\ln x \cdot z$	-1.236	***	0.161	-1.253	***	0.161	-1.258	***	0.163	-1.236	***	0.163
N	-0.032	***	0.013	-0.016		0.021	0.020		0.023	0.003		0.024
A	0.007	***	0.002	0.006	***	0.002	0.009	***	0.002	0.007	***	0.002
lnIH	-0.003		0.003	-0.024		0.018	-0.053	***	0.019	-0.054	***	0.019
$1/2N^2$				0.011		0.015	0.023		0.016	0.020		0.016
$1/2A^2$				-0.014	***	0.006	-0.018	***	0.006	-0.018	***	0.006
$1/2(\ln IH)^2$				0.001	***	0.000	0.001	*	0.000	0.001	*	0.000
$N \cdot A$				0.009		0.009	0.005		0.009	0.007		0.009
$N \cdot \ln IH$				0.005	**	0.002	0.005		0.003	0.004		0.003
$A \cdot \ln IH$				0.000		0.002	-0.001		0.002	-0.002		0.002
$\ln x \cdot N$							0.076	***	0.025	0.084	***	0.025
$\ln x \cdot \ln IH$							-0.003		0.006	-0.005		0.006
$\ln x \cdot A$							-0.004	*	0.002	-0.003		0.003
$\ln y_2 \cdot N$							-0.013		0.008	-0.011		0.008
$\ln y_2 \cdot \ln IH$							0.004	*	0.002	0.003		0.002
$\ln y_2 \cdot A$							-0.005	***	0.001	-0.005	***	0.001
$z \cdot N$							0.169		0.364	0.255		0.371
$z \cdot \ln IH$							0.200	**	0.090	0.194	**	0.091
$z \cdot A$							-0.183	***	0.046	-0.185	***	0.046
WN										0.067	***	0.022
WA										0.007	***	0.003
WlnIH										-0.011	**	0.005
Intercerpt	-0.060	***	0.022	-0.055	**	0.026	-0.025		0.027	-0.013		0.027
Time dummies	Yes			Yes			Yes			Yes		
Fixed Effects	Yes			Yes			Yes			Yes		
Significance F-test (a)	1294.1	***		1069.8	***		868.4	***		813.8	***	
F test that all α_i=0	96.2	***		95.7	***		97.1	***		95.7	***	
Degrees of freedom	4644			4638			4629			4626		
Obs.	4964			4964			4964			4964		
# parameters	320			326			335			338		
# function parameters	13			19			28			31		
# fixed effects (b)	291			291			291			291		
# time dummies (b)	16			16			16			16		

Notes: (a) This F test includes the distance function coefficients (except the intercept) and the set of time dummy parameters. (b) One effect is excluded due to an intercept is estimated.

Table 3. Parameter estimates of the auxiliary regressions (dep. var.: number of farms)

	All parishes			Beef-oriented			Dairy-oriented			Mix-oriented		
Variable	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.	Coef.		s.e.
N	-0.030	*	0.016	-0.115	**	0.032	-0.137	***	0.038	0.037	*	0.012
A	0.002		0.002	0.016	***	0.004	0.005		0.002	0.000	**	0.001
lnIH	-0.001		0.003	-0.002		0.007	0.025		0.006	-0.007		0.002
WN	0.066	***	0.024	0.177	***	0.046	-0.003		0.046	0.036	**	0.020
WA	-0.006	*	0.003	0.035	***	0.008	-0.005	***	0.004	0.000	***	0.002
WlnIH	0.007		0.006	-0.057		0.013	0.041	*	0.009	0.029	***	0.005
Intercerpt	3.185	***	0.012	2.746	***	0.022	3.631	***	0.019	3.525	***	0.011
Time dummies	Yes			Yes			Yes			Yes		
Fixed Effects	Yes			Yes			Yes			Yes		
Significance F-test [(a)]	165.7	***		31.69	***		134.4	***		295.6	***	
F test that all α_i=0	238.1	***		165.1	***		327.1	***		497.5	***	
Degrees of freedom	4650			2202			650			1754		
Obs.	4964			2363			714			1887		
# parameters	314			161			64			133		
# fixed effects	291			138			41			110		
# time dummies	16			16			16			16		

Note: (a) This F test includes the coefficients of all LC variables and the set of time dummy parameters.

Table 4. Overall LCE effects

		All parishes		
LCE	Obs	Unconditional	Conditional	farms
Total	1,056	16.36	10.82	1.77
Direct	1,056	4.90	7.08	-3.43
Indirect	1,056	11.46	3.75	5.21
		Beef-oriented parishes		
LCE		Unconditional	Conditional	farms
Total	308	-5.55	-5.92	0.82
Direct	308	-14.51	-8.98	-4.85
Indirect	308	8.96	3.06	5.67
		Dairy-oriented parishes		
LCE		Unconditional	Conditional	farms
Total	223	30.24	22.50	16.79
Direct	223	21.06	19.59	6.42
Indirect	223	9.18	2.91	10.36
		Mix-oriented parishes		
LCE		Unconditional	Conditional	farms
Total	525	23.32	15.68	14.37
Direct	525	9.42	11.19	0.81
Indirect	525	13.90	4.50	13.56

Figure 1. Number of LC processes in Asturias (1963-2017)

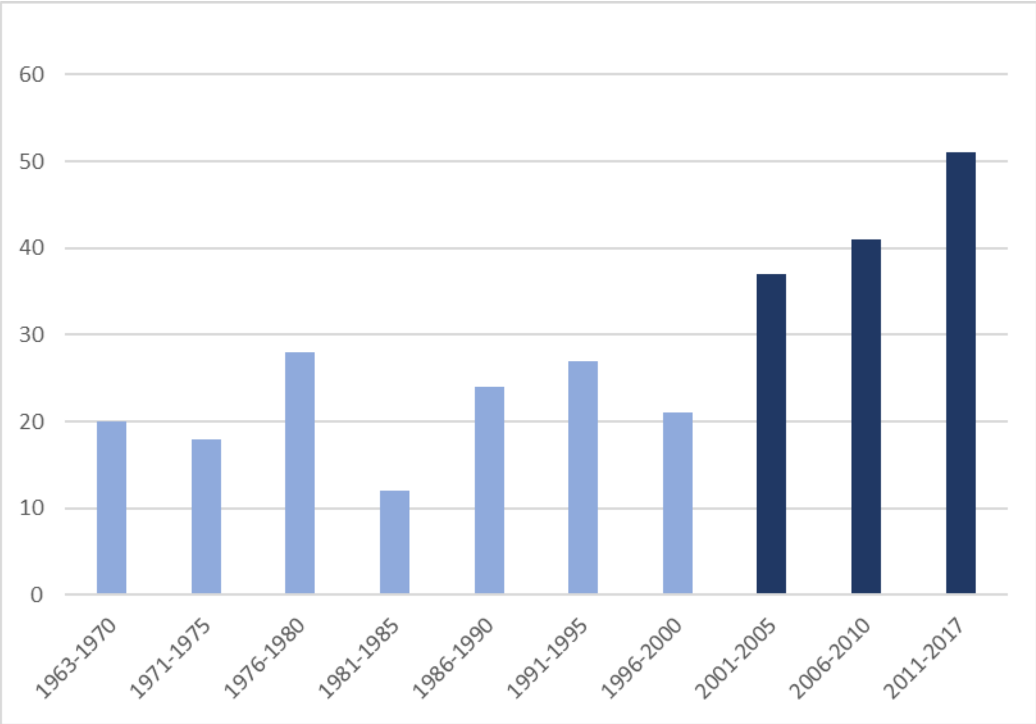


Figure 2. Land consolidation processes in Asturias (1963-2000)

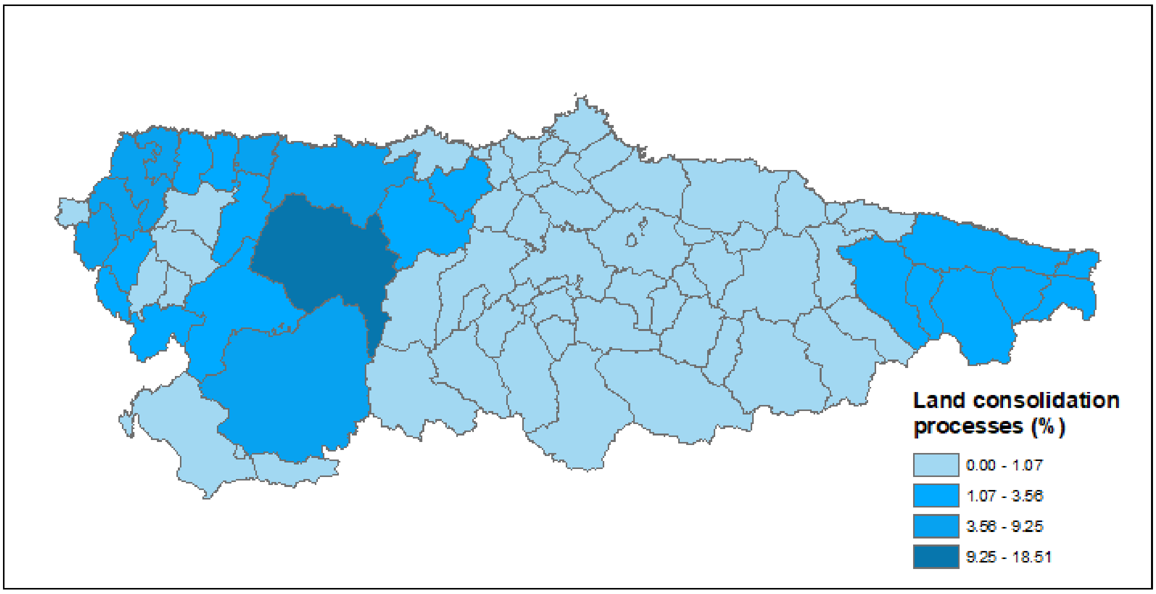


Figure 3. Land consolidation processes in Asturias (2001-2017)

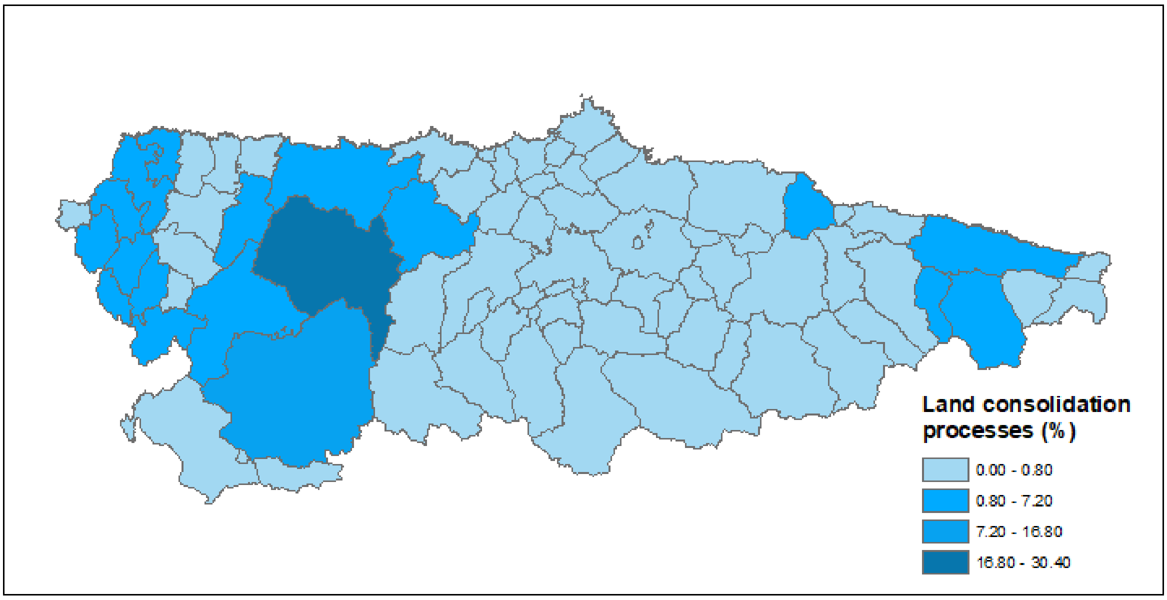


Figure 4. Temporal evolution of farms size and farm numbers.

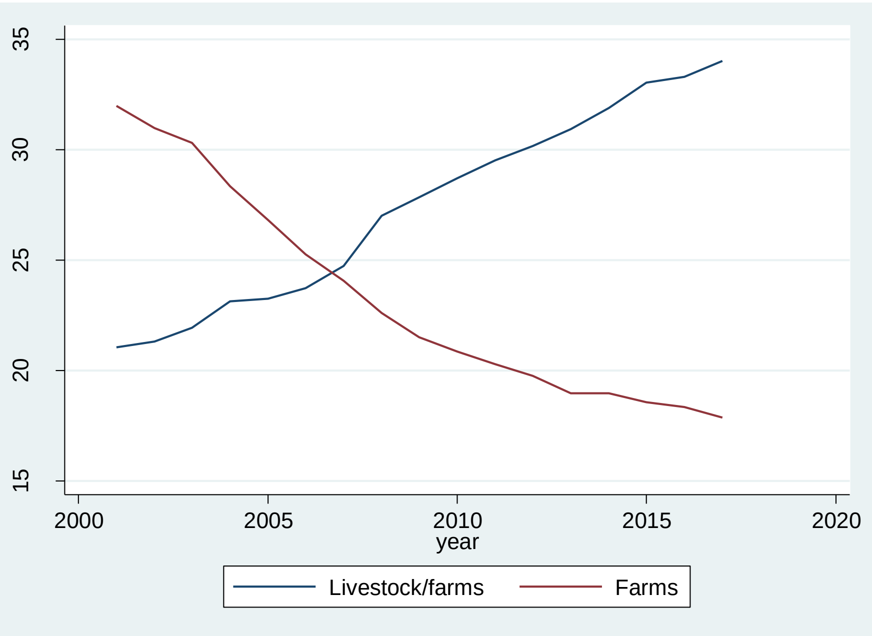
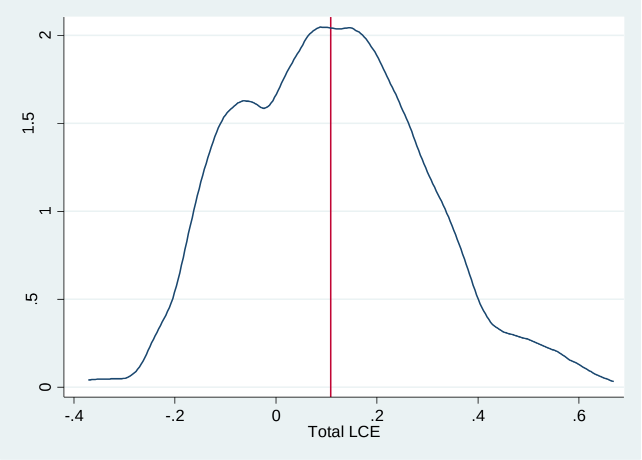
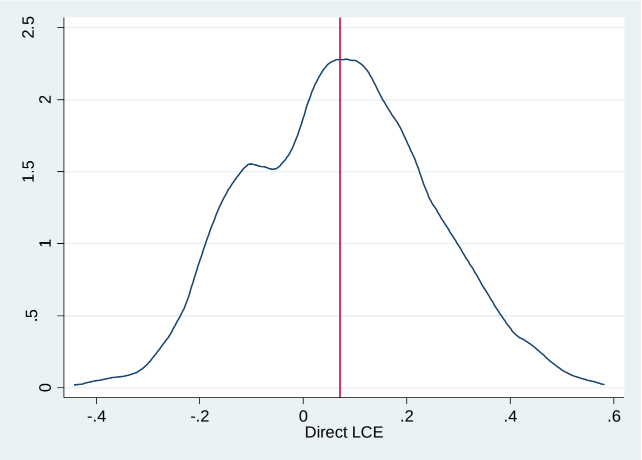


Figure 5. Distribution of LC effects

(a)



(b)



(c)

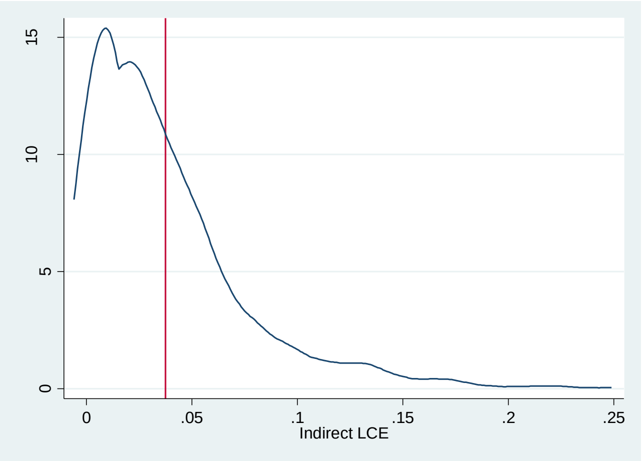
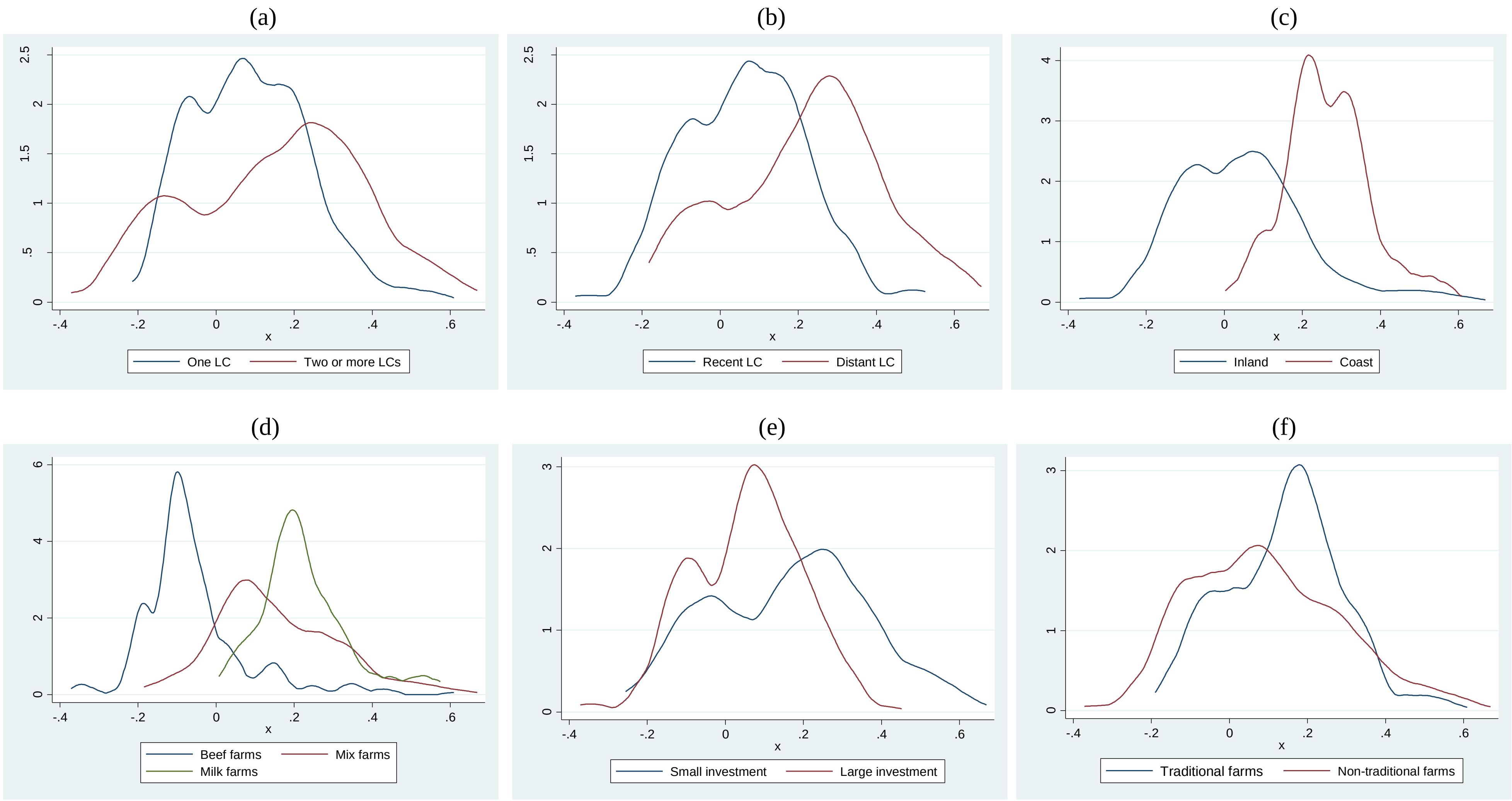


Figure 6. Total LC effects by groups



Appendix

Literature review on land consolidation (LC)

Paper	Objective	Sample	Methodology	Results
Burger (2001)	Analyze the agricultural transformation, land redistribution and land tenure and the role of agriculture in the Hungarian economy	309 farms in 11 counties of Hungary in 1998	Questionnaire	LC has taken place mainly by renting. Rented land increases with the increasing farm Size
Coelho et al. (2001)	Proposition of a model that incorporates methods for the evaluation of the performance of the agricultural system before and after the LC project	The model was applied to the Valenca LC in 1989, before project execution, and in 1995 after implementation	The model evaluates each efect of the project (land, irrigation and drainage and road reconstruction) on a technical and social basis and estimates its economic impacts.	The results suggest that a multidisciplinary approach, supported by robust models, can be used as a reliable basis for the evaluation and decision-making process of LC projects
Crecente et al. (2002)	Review the process of LC in Galicia analyzing economic, social and environmental effects	Parishes with and without LC processes. Cases of two municipalities	Comparative analysis of consolidated and non-consolidated areas in Galicia	LC contributes to retaining farmland in agricultural use and improves the population evolution in rural areas, although there are changes in use from cropland to pasture land
Vitikainen (2004)	Discuss the similarities and differences in the LC procedure in various European countries	Objectives and contents of LC in Finland, Germany, the Netherlands and Sweden	Comparison of the organisation, objectives, legal procedure, costs and financing, and the development of LC between countries	The demand for LC arises from the need for promoting the appropriate use of the land. There are differences in the objectives and procedures of LC between countries related to factors like historical trends, culture, tradition and legislation
Wu et al. (2005)	Examine and measure the impact and cost-effectiveness of the comprehensive agricultural development program on Chinese agriculture	Data collected from a survey to 227 Chinese farm households	This paper uses a production function approach	The program has improved land quality and the productivity of household crop production, and overall has been cost-effective

Lerman and Cimpoies (2006)	Examine LC within of process of agrarian reform	Several surveys in Moldova, made in different years and previously published	Analysis of several surveys	LC leads to better economic performance. Land leasing is used as a market mechanism for consolidation
Miranda et al. (2006)	Examine the geographic, agricultural, socioeconomic and environmental effects of LC in Galicia since the 1950s	Databases related to 315 Galician municipalities and 3,793 parishes. Data from 1,129 LC processes related to the period 1950-2001	Methodology drawn up by the European Union for evaluation of its socioeconomic programs	LC has in general made a positive contribution to slowing rural depopulation
Yu et al. (2010)	Identify and classify the ecological risks in LC. Develop a framework of the theory and method to assess the change of ecological risk degree before and after LC	A case study of a LC project in Chongyang County, Hubei Province, China	Analytical hierarchical processing (AHP) method to the data resources from the LC project in Southern China to allocate weightings to the indices of ecological risk (ER), and to set up an integrated index system for the ecological risk identification. This integrated index system encompasses the ecological risks with three factors (water, soil and biology) and 14 indices	The ER is reduced from 58.02 to 28.8 after LC and the degree of ecological risk is down from Degree III to Degree IV. The water ER is reduced from 21.53 to 6.16, its contribution to reduce the ecological risk is 53%. The reduced ERs of soil and biology are respectively 12.79 and 1.06, their contribution of ecological risk reduce is lower than water
Hartvigsen (2014)	Study of land reform in 25 countries in Central and Eastern of Europe from 1989 and onwards and provide an overview of applied land reform approaches	Land reform approaches applied in 25 countries in Central and Eastern Europe from the Baltic and Central European countries in the West to Russia and the small Trans-Caucasus countries in the east, and to the Balkan countries in the south	With a basis in theory on land fragmentation, the linkage between land reform approaches and land fragmentation is explored	Land fragmentation is often hampering agricultural and rural development when both land ownership and land use is highly fragmented

Lisec et al. (2014)	Investigate the opinion of LC participants about LC	Responses to a questionnaire of 254 land owners from 3 areas of Slovenia in 2011	Survey conducted on a sample of private land owners involved in selected LC projects	The active participation of land owners contributes to their comprehension of the aims and to their satisfaction with the results of the LC
Zhang et al. (2014)	Identify the changes resulting from the LC implementation, and to develop a parametric approach to assess the resource–environment effects	Case study of Tianmen LC project in Hubei Province of China	Use of indexes to assess the different effects of LC	LC causes positive and negative effects. Positive effects were demonstrated in agricultural production capacity and in its costs. The negative effects were expressed by the ecosystem services value, landscape diversity and human disturbance intensity
Guo et al. (2015)	Identify and measure the effect of LC on the multifunctionality of cropland ecosystems	Analysis of county scale LC projects in the 31 provinces of China (period 2006-2012)	Set pair analysis methodology. Variable fuzzy sets analysis	LC have significantly improved the production function of cropland, driven investment in agriculture, promoted development of the rural agricultural economy, maintained food security and stability in the rural area. However, it also impaired rural ecological benefits in some provinces
Wang et al. (2015)	Understand how LC affects landscape patterns and ecosystems investigating the ecosystem service value and the ecological connectivity in a consolidated area of Da'an city from 2008 to 2014 using a revised ecological connectivity index	Consolidated area of Da'an city from 2008 to 2014 (China)	Use a ecosystem service evaluation and a revised ecological connectivity index	LC has certain negative influences on the ecosystem services. LC could change the ecological connectivity as well as the land use structure
Hiironen and Riekkinen (2016)	Evaluate agricultural impacts and profitability of LC	12 LC projects implemented in Finland	Standard statistical methods, production cost calculations and feasibility analyses	LC is an effective and feasible land management tool for the improvement of property structure. Due to the improvement of property structure the average production costs decrease 15%
Jiang et al. (2017)	Propose an assessment model to estimate the improvement of land productivity potential via LC	Region of Shenyang City (China)	Use of a system for assessing the cultivated land productivitypotential before and after LC	The effect of the concentration is based on an increase of more than 20% in the potential productivity of the land
Jin et al. (2017)	Evaluation of the effectiveness of LC policy	Detailed geo-spatial information for 5,328 LC	Generalized Linear Mixed Model (GLMM) to predict	The overall effectiveness of LC in improving agricultural productivity is

		projects implemented between 2006 and 2010 in China	project effectiveness incorporating selected biophysical, social-economic variables as fixed effects and province variables to model random effects	low. There are also clear regional differences.
Luo and Timothy (2017)	Evaluation of the performance of LC in terms of rural households' levels of satisfaction in rural China	Data gathered via questionnaires in the regions of Hangzhou, Changsha, and Guiyang (China)	Probit model	Overall satisfaction rate was 76.5%. Residents' satisfaction with LC depends, among others, on farmers' level of education, family size, level of agricultural mechanization, and their participation in rural production cooperatives
Demetriou (2018)	Present and discuss the development, implementation and evaluation of two different automated valuation models (AVMs) for a case study LC	Case study area in Cyprus	Estimation of two hedonic price models combined with a geographical information system (GIS)	The AVM is highly efficient compared to conventional land valuation methods and provide transparency
Du et al. (2018)	Propose a straightforward method to assess agricultural productivity changes using remote sensing data	Moderate Resolution Imaging Spectroradiometer NDVI time series from 2001 to 2013 and data on LC projects completed in China in 2006 and 2007	Two indexes were used to evaluate the effects of LC: the rate of change in the mean annual NDVI and the coefficient of variation of this variable before and after consolidation	78.67% of projects in 2006 and 78.32% of those in 2007 proved effective at either improving or stabilizing productivity
Dudzińska et al. (2018)	Assessment of the socio-economic effects of consolidations at the meso-level in rural areas	Polish communes in which both traditional and infrastructural consolidations had been implemented over an area of at least 15% of the commune's area	The level of socio-economic development was assessed based on an indicator of the rate of changes, calculated as the difference between the levels of commune development indicator for the years 2004 and 2016	Implementation of traditional consolidations of agricultural land is one of the factors contributing to an increase in the level of socio-economic development of rural areas
Li et al. (2018)	Investigate the challenges in implementing LC in rural China and to pose policy implications for rural sustainability	LC project in a village community of Shandong Province (China)	Analysis and reflection on the process of LC	LC is needed to coordinate and improve the changing human-land relationship in rural China. It is needed an expanded rural land market.

				LC should be implemented by respecting local stakeholders' willingness and request
Nilsson (2018)	Examine the role of land use consolidation on agricultural productivity among smallholder farmers in Rwanda	Random sample of 1,538 households across Rwanda of which 25 per cent participated in land use consolidation between 2010 and 2014	Household-level data are used to estimate a fixed-effects model with matched control groups to mitigate selection bias	Positive association between land use consolidation and crop yields (among farms with landholdings greater than one hectare)
Shi et al. (2018)	Research on LC projects by integrating landscape pattern analysis with production, living, and ecological benefit assessments	Two municipal LC projects in China were selected for analysis	By an evaluation index system, the authors quantitatively estimate the dynamic changes in the production, life and ecological benefits of the two project areas	LC has directly or indirectly improved landscape ecological patterns. LC has improved the balanced distribution of cultivated land and the concentrated distribution of construction land in the project area
Zeng et al. (2018)	Evaluate the impacts of LC on agricultural technical efficiency of producers	Data from a field survey executed during July 2010 and July 2016. A total of 900 producers were chosen randomly from 30 LC projects in the Jiangsu Province (China)	Stochastic frontier analysis production function	Land tenure transfer, land fragmentation, non-agricultural income, and crop diversity has undergone significant changes after LC. The overall agricultural technical efficiency of producers had also increased considerably after LC
Zhang and Zhang (2018)	Analyze the interference by human activities caused by LC engineering in terrestrial ecosystems	Analysis of a project area located in Mugong Village in Guanling County (China)	GIS technology, ecological values, landscape pattern indexes, and an ecological risk evaluation were used to construct an ecological sensitivity evaluation index	The project area was divided into sensitivity zones according to the results that provide suggestions for future land management decisions
Colombo and Perujo-Villanueva (2019)	Propose a methodology for assessing ex-ante the most suitable areas in which LC initiatives could be carried out	The case study focuses on olive groves in the Andalusia region (Spain). Interviews to 72 landowners	Interviews to 72 landowners and use of a methodology for assessing ex-ante LC projects	LC procedure in the areas identified would bring about a noticeable improvement in the property structure and production cost savings of between 5.8% and 15.3%

Janus and Markuszewska (2019)	Verify the hypothesis of persistence of favorable basic parameters of LF and other factors affecting the efficiency of agricultural production after LC	Jabłonka commune located in the southern Poland	Comparison of indicators for all villages from the commune selected	There is a multi-generational and positive impact of LC on the development and functioning of rural areas. This is evident regarding the average plot size, road accessibility, the land fragmentation indicators, and the lowest level of land abandonment
Zhou et al. (2019)	Analyze the mechanism and path behind LC boosting poverty alleviation	Data on LC in Fuping County (China)	Revision of the evolution of China's land policies related to poverty alleviation since 1978. Case study method	LC has contributed to increasing cultivated land area, promoting agricultural production scale, improving rural production conditions and living environment, alleviating ecological risk and supporting for rural development and poverty alleviation