IMPLICATIONS OF LAND MARKET IMPERFECTIONS ON POLICY DESIGN

by

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Kyiv School of Economics

Abstract

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Land markets all over the world are diversely regulated, although a vast stock of empirical literature seems to suggest that unrestricted land market is the best policy design option. Since diversity of regulations proves this unlikely, it is surprising that little attention is paid in the academic literature to the theory that would allow to choose land market design based on welfare implications of various restrictions.

In this work, we build upon the framework described in the literature in order to derive an optimal choice of maximum land holdings restrictions in the presence of land market imperfections. Imposing such restrictions together with reduction of transaction costs in land markets could reduce market imperfections and improve welfare in the economy by reallocating the land between large and small economic agents according to their marginal productivities.

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GLOSSARY

MB. Marginal benefit. The benefit gained cultivating an additional unit of land.

MC. Marginal cost. The cost incurred by cultivating an additional unit of land.

MVP. Marginal value product. The market value of farm output resulting from one additional unit of land.

TE. Technical efficiency. The ratio of the observed farm output to the maximum feasible output as determined by the production function.

Chapter 1

INTRODUCTION

Agricultural land markets all over the world are quite regulated (Deininger and Feder, 2001), and the burden of regulations is diverse. There is substantial heterogeneity of land markets and regulations in the EU, ranging from the heavily regulated markets in France and Hungary to the markets in the UK, Greece, and Ireland with very little regulation (Swinnen et al., 2016).

Typically, policy makers impose various regulations to address undesirable consequences associated with land markets, and these consequences are driven by market imperfections and historical developments. For instance, in Western European countries, a land regulatory environment ended up biased towards a more protection of small tenants' rights in the power struggle with powerful landlords. In Eastern European countries (former Soviet-bloc countries), the power struggle is reversed—dismantling of the centrally planned economy and privatization of state land (either through restitution or redistribution to rural population) resulted in environments where large farms rent thousands of small land plots from families (Swinnen et al., 2016). For example, in Ukraine, agricultural enterprises rent in total about 20 mln ha of agricultural land from about 6.9 million people (Deininger et al., 2017a).

In general, land market design options aimed at addressing market imperfections issues take one of two forms (Deininger and Feder, 2001): transferability restrictions and land holdings/ownership restrictions. Transferability restrictions include (Rolfes, 1999) moratoria on land sales, restrictions on purchase of land by foreigners, restrictions on land sales to ensure continued agricultural use, land lease restrictions, and priority rights to purchase land parcels. Land holdings/ownership restrictions include (Rolfes, 1999) maximum landholding size restrictions (with the main intention of preventing unregulated land concentration) and minimum landholding size restrictions (with the main intention of preventing land fragmentation into economically inefficient units).

Policy measures listed above have often been described in the literature as not fulfilling the stated objectives and having adverse effects on the economy. E.g., according to Hayami and Otsuka (1993), inability to trade their own land deprives the landowners from access to credit, whereas imposing maximum landholding size restrictions leads to excessive red tape and corruption (Deininger 2003). Nivievskyi et al. (2016) list potential problems arising from adhering to these land market design options, including the following ones: credit market development is hindered, demand for farmland is reduced, transaction process becomes complicated, and productivity is adversely affected. As a result, in many cases restrictions on land sales markets seemed justified, but enforcement difficulties generated distortions that only worsened the situation. Governments' measures to improve land markets outcomes all over the globe increased transaction costs for participants or drove transactions to informal sector, reducing the welfare of all participants (Deininger, 2003; Ciaian et al., 2012a; Ciaian et al., 2012b).

From the policy making point of view, the above mentioned stock of literature seems to be suggesting that a land market with no restrictions would be the best policy design option. However, political economy of the issue at stake renders this outcome unlikely, diversity of land markets and rigidity of regulations (Swinnen et al., 2016) being a good evidence for that. Therefore, it seems that policy makers will always be confronted with a need to make an ex-ante choice on relevant land market design options and their stringency.

In Ukraine, there is ongoing debate on the design of its agricultural land sales market (Deininger et al., 2017a; Deininger et al., 2017b) after the sales moratorium is lifted. This issue is important for Ukraine because 69% of its total land area is agricultural land (Nivievskyi and Strubenhoff, 2017), and agricultural sector of economics accounts for a large share of GDP growth.

One of the restrictions being discussed in the circulating draft laws is the maximum amount of land that individuals and legal entities are allowed to own or cultivate. In the *Concepts of Agricultural Land Market Design* presented at the All-Ukrainian Land Forum that took place April 10, 2019 by the Acting Head of the Committee on Agrarian Policy and Land Relations of Verkhovna Rada of Ukraine O. Bakumenko[1], two variants of introducing restrictions have been proposed. According to the so-called regulated version of the land market, legal entities will not be allowed to own more than 30% or 15% of agricultural land in any given rayon (district) or region (oblast) of Ukraine, respectively, but not more than 20 thousand ha. According to the so-called liberal version of the land market, legal entities will not be allowed to own more than 30%, 20%, or 10% of agricultural land in any given hromada (local community), rayon, or region of Ukraine, respectively, but not more than 20 thousand ha.

Land holdings restrictions, should they be introduced, would not be unique to the land market in Ukraine. E.g. in Lithuania, legal entities cannot own more than 500 ha (Ciaian et al., 2012b); in Hungary, legal entities cannot own or rent more than 300 ha (Ciaian et al., 2012a); in France, Germany, and Sweden, transactions with land need to be approved by authorities (Ciaian et al., 2012b), lest the land markets become overly consolidated and non-transparent. However, no empirical or theoretical justifications are given for the cutoff points proposed in Ukraine.

[1] http://agroportal.ua/ua/news/ukraina/opredeleny-varianty-otkrytiya-rynka-zemli

The research objective of the thesis is to build upon a partial equilibrium framework described in the literature to justify land holdings restrictions in the presence of land market imperfections in the form of transaction costs (e.g., bargaining costs, costs related to asymmetric information, administrative costs related to land transfers, etc.) and imperfect competition.

The rest of the thesis is structured as follows. Chapter 2 presents an overview of the relevant academic literature on modeling land and credit market imperfections. An overview of the basic theoretical framework used in the thesis is given in Chapter 3. Methodological approach to estimating optimal land holdings restrictions is also discussed in this chapter. In Chapter 4, a description of the data used is provided. Chapter 5 provides obtained empirical results. Chapter 6 concludes the thesis with summarizing discussion, stressing on the implementation issues of the policy design options argued for in the work.

C h a p t e r   2

LITERATURE REVIEW

2.1. Theoretical Studies

One of the first theoretical models aimed at explaining the effect of rural market imperfections was developed by Vranken and Swinnen (2006). The model sought to explain the determinants of household farms' participation in land rental markets in transition countries. In the model, a representative household produces certain goods using amount of land $T = \bar{T} + T^i - T^o$, where $\bar{T}$ is the initial endowment of land, T^i is the amount of land rented in, and T^o is the amount of land rented out. To cultivate the land, the household employs hired labor L^i and its own (family) labor L^f. Apart from that, members of the household can be employed off farm, with L^o measuring this amount of labor. The amount of labor off farm is subject to the upper limit constraint $\bar{L}^o$.

The household majximizes its utility subject to several constraints as follows:

$$\max_{\substack{L^f, L^i, L^o, l, \\ T^i, T^o, X}} U\left(f\left(L, T, X, \bar{Z}\right) - p_X X - r^i T^i - w^i L^i + r^o T^o + w^o L^o, l \right),$$

$$\text{s.t.} \quad \begin{array}{l} p_X X + r^i T^i + w^i L^i \le B + \bar{M} + r^o T^o + w^o L^o \\ L^o \le \bar{L}^o \\ \bar{L} = L^f + L^o + l \end{array} , \qquad (1)$$

where f is the production function; L is effective labor input on the farm; X is the amount of purchased inputs priced at p_x; $\bar{Z}$ is the amount of non-tradable inputs and fixed productive assets; l is leisure; r^i and r^o are input and output land rental prices, respectively; w^i and w^o are the wages paid to hired laborers and earned by working off farm, respectively; B is the amount of credit resources borrowed; $\bar{M}$ is initial wealth endowment.

The solution to (1) yields the following major results: a household is more likely to rent land in rather than out if the marginal product of land is higher; the more land the household owns, the less it is likely to rent in and the more it is likely to rent out, ceteris paribus; the household is more likely to rent in if the rental price is lower; transaction costs in the rental market reduce both renting in and renting out; more stringent credit market constraints reduce the likelihood that the household will rent in; the more family labor is used on farm, the more the household is likely to rent in; higher wages reduce renting in.

One major shortcoming of the model is that it seeks to explain the behavior of a representative household, but falls short of shedding light on the effect of various policy design options on the market structure given market imperfections. These issues were tackled by Ferguson et al. (2006). In their framework, a representative farmer solves the following profit-maximizing problem:

$$\begin{gathered} \max E\left[P_0^t\right]Q^t - w_1^t x_1^t - w_2^t\left(r^t\right)x_2^t \\ \text{s.t. } Q^t = f\left(x_1^t, x_2^t\right), \end{gathered} \tag{2}$$

where $E\left[P_0^t\right]$ is the expected farm output price; Q^t is the output of the farm; f is the production function; w_1^t is the price of a variable input (e.g., fertilizer); x_1^t is the quantity of the variable input used; $w_2^t\left(r^t\right)$ is the observed price of land services; r^t is the stringency of the government regulation; x_2^t is the amount of land services used. The authors assume that $w_2^t = \lambda^t + \psi r^t$, where λ^t is the price of land services in a free market, and ψ measures the effect of the ownership regulation on the observed land price.

Having solved (2), the authors show in the partial equilibrium framework that effect of ψ is negative, i.e. the more stringent are the ownership regulations (for instance, non-residents are not allowed to access land market), the more farmland prices are reduced. This theoretical result provides support for the evidence that special interest groups seeking to impose entry barriers into the industry benefit from reduced rental prices (Stigler, 1975).

A more thorough model appeared in (Ciaian and Swinnen, 2006) as an attempt to analyze the impact of imperfections in the land market on the welfare effect of subsidies. In this regard, this paper was the first one to explicitly incorporate imperfections, both in the form of transaction costs and local market power exhibited by corporate farms leading to imperfect competition.

In the paper, farms are divided into (large) corporate farms and (small) individual farms. Individual farms can start their business by renting the land currently being cultivated by the corporate forms, incurring transaction costs t in the process. Individual farms solve the following profit-maximizing problem:

$$\max \Pi^I = pf^I\left(A^I\right) - (r+t)A^I, \tag{3}$$

where p is the output price; $f^I\left(A^I\right)$ is the increasing production function of individual farms, which depends on the amount of land rented A^I; r is the rental price of the unit of land. Corporate farms solve the following similar profit-maximizing problem:

$$\max \Pi^C = pf^C\left(A^C\right) - r\left(A^C\right)A^C, \tag{4}$$

where $r\left(A^C\right)$ is a rental price being an increasing function of land rented, thus explicitly indicating that corporate farms possess certain market power.

Solution to (3) and (4) predicts that when the corporate farms are assumed to dominate the market, they in fact use less land than in the case when the market is competitive. Rental prices are also lower for corporate farms in the absence of competition and the presence of transaction costs. However, the two market imperfections have different effects on rental prices for individual farms: on the one hand, imperfection competition lowers the rental prices; on the other hand, transaction costs increase the rental prices. The net effect thus depends on the relative size of transaction costs.

Landowners lose in any case, due to decrease in the rental prices in comparison to the competitive ones. The total welfare effect is negative.

Ciaian (2007) extended this model by explicitly taking into account well-being of landowners, expanding (3) and (4) with additional profit maximization problem

$$\max \Pi^L = rA^T, \tag{5}$$

where $A^T = A^I + A^O$ is the total amount of land supplied. Implications of this extended framework do not differ from the ones discussed above.

In (Ciaian and Swinnen, 2009), credit market imperfections were added to the framework. In particular, (3) is modified to include the second input to the production function, fertilizers *K*, leading to the following maximization problem:

$$\begin{gathered} \max \Pi = pf(A,K) - rA - kK(1+i) \\ \text{s.t. } kK(1+i) \leq S(W), \end{gathered} \tag{6}$$

where *k* is the per unit price of fertilizers; *i* is the interest rate; *S* is the maximum amount of credit that a farm can borrow; *W* represents various farm characteristics (reputation, assets, etc.), so that $\frac{\partial S}{\partial W} > 0$.

Two major assumptions are made by the authors. First, the economy is assumed to be small and open, which implies that the fertilizer price and output price are fixed. Second, the agriculture is small in terms of credit use so that agricultural loans do not affect interest rates.

Major result after solving (6) is as follows: the more credit constrained the farms are, the less fertilizers they can use, the lower their land demand is, and hence the lower the equilibrium rent is, which means the farmers gain in their surplus. The landowners, however, lose due to decreased rental payments they receive.

2.2. Empirical Research

Vranken and Swinnen (2006) tested the hypotheses described in Sect. 2.1 by estimating two censored Tobit regression models. In the first one, the dependent variable was the amount of land rented out, whereas in the second one, the dependent variable was the amount of land rented in. The data used were the household level data collected in a 1998 survey of Hungarian rural households and county level data from the Hungarian statistical office with more than 1,400 observations in total.

In both models, covariates included household characteristics (such as age and education of the household head), county-level land characteristics (such as quality of the land as reported by the statistical office and land sales price), regional dummy variables to capture fixed effects, and a number of dummy variables to capture land market imperfections (e.g., variable reflecting domination of the land market and a variable reflecting outstanding loans).

The major conclusions from this empirical exercise were as follows: ceteris paribus, households who own more land are more likely to rent it out and less likely to rent it in; there is a highly significant positive relationship between buying of land in the previous years and renting in of land in the current period; domination of land market has a highly significant negative effect on renting in of land by households; credit market constraints have a very significant positive (negative) effect on renting in (out). However, as mentioned in Sect. 2.1, this research did not focus on welfare implications for the economy.

In his research of the effect of land imperfections in the form of poor land governance on farm productivity levels in Ukraine, Nivievskyi (2017) comes to the important conclusion that lower rayon level productivity is associated with a higher share of state owned land in the rayon and higher concentration in land markets at the rayon level. By applying the two-stage methodology, wherein the production function is estimated first, and then semi-parametric regression is used to model determinants of the rayon-level productivity, to the farm-level accounting data provided by the State Statistics Service of Ukraine (balanced panel of 17,000 observations over the period of 2013–2014), the author finds out that the covariates "average state parcel size" and "Herfindahl index" have a strong negative effect on the rayon productivity.

In above discussion, land market concentration is estimated either using a simple cut-off rule or using indices such as Herfindahl index. However, according to (Sheldon and Sperling, 2003), a more thorough approach to estimating market concentration, called new empirical industrial organization approach, allows to use detailed knowledge about a specific industry to arrive at more precise estimates. There are two major methods of estimating market power, production theoretic approach (PTA) proposed by Applebaum (1982) and general identification method (GIM) described in Bresnahan (1982). The advantage of the first one is that it accounts for total information about the production technology (Perekhozhuk et al., 2016), whereas the second one does not require data on profit, cost, revenue, or production (Perekhozhuk et al., 2016).

Perekhozhuk et al. (2016) performed a meta-analysis of 38 empirical studies of the market power in the agro-food industries in various countries and found out that estimates of market power obtained using PTA are generally higher than their counterparts obtained using GIM.

Above studies suggest the importance of recognizing land market imperfections, especially market concentration and imperfect competition. In the following chapter, we will discuss a methodology for deriving land holdings restrictions aimed at mitigating this issues by reallocating the land between large and small farms according to their marginal productivities.

C h a p t e r 3

METHODOLOGY

3.1. Basic Theoretical Framework

In this section, we will build upon the theoretical framework of Ciaian and Swinnen (2006) in order to gain insight as to how land holdings restrictions can be efficiently used to mitigate imperfection issues in land rental markets.

Let us denote by A_T the total supply of arable agricultural land, and assume that $A_T = A^C + A^I$, meaning that all the land belongs to landowners who can rent out the amount of land A^C to corporate (large) farms and the amount of land A^I to individual (small) farms. For simplicity, we assume that neither corporate nor individual farms rent out their land and cultivate all the land they rent in.

The profit of a representative individual farm can be formulated as $\Pi^I = p_y f^I\left(A^I, K^I, L^I, M^I\right) - (r+t)A^I - hK^I - wL^I - mM^I$, where p_y is the output price of the product; $f^I\left(A^I, K^I, L^I, M^I\right)$ is the production function increasing in inputs but with diminishing returns; A^I is the amount of land cultivated; K^I is the amount of capital; L^I is the amount of labor employed; M^I is the amount of materials used (e.g. fertilizers, machine spare parts, fuel, etc.); *r* is the rental price for land; *t* are transaction costs in the rental market; *h* is the per unit price of capital; *w* are the wages paid to the employed labor force; *m* are material costs.

The profit function of a representative corporate farm can be similarly formulated as $\Pi^C = p_y f^C\left(A^C, K^C, L^C, M^C\right) - r\left(A^C\right)A^C - hK^C - wL^C - mM^C$, where $r\left(A^C\right)$ is a rental price as an increasing function of land rented. Dependence of *r* on A^C shows that corporate farms may exhibit certain market power in the land rental market.

Profits of the landowners are given by $\Pi^L = r\left(A^C + A^I\right)$.

In case of a perfectly competitive land rental market, where transaction costs are zero and corporate farms are price takers in the input market, the optimal allocation of land from the social planner's point of view would be determined by solving the following optimization problem:

$$\begin{gathered}\max\left(\Pi^I + \Pi^C + \Pi^L\right) = \\ = p_y f^I\left(A^I, K^I, L^I, M^I\right) - hK^I - wL^I - mM^I + \\ + p_y f^C\left(A^C, K^C, L^C, M^C\right) - hK^C - wL^C - mM^C \\ s.t.\quad A_r^I + A_r^C = A_T\end{gathered} \tag{7}$$

The first order condition for (7) with respect to land immediately gives that the optimal allocation of land between corporate and individual farms corresponds to the situation where marginal value products (MVP) of the two farms are equal: $p_y \frac{\partial f^C}{\partial A^C}\left(A^*\right) = p_y \frac{\partial f^I}{\partial A^I}\left(A_T - A^*\right)$. The corresponding optimal rent level in the market is then given by $r^* = p_y \frac{\partial f^C}{\partial A^C}\left(A^*\right) = p_y \frac{\partial f^I}{\partial A^I}\left(A_T - A^*\right)$.

The same solution can be obtained by solving the problem as a competitive equilibrium one:

$$\max \Pi^I = p_y f^I \left(A^I, K^I, L^I, M^I \right) - rA^I - hK^I - wL^I - mM^I$$
$$\max \Pi^C = p_y f^C \left(A^C, K^C, L^C, M^C \right) - rA^C - hK^C - wL^C - mM^C \qquad (8)$$
$$s.t.\ \ A^I + A^C = A_T$$

This case is illustrated in Fig. 1, in which derived demand for land functions for corporate farms D^C and for individual farms D^I are defined by equations $r = p_y \frac{\partial f^C}{\partial A^C}$ and $r = p_y \frac{\partial f^I}{\partial A^I}$, respectively.

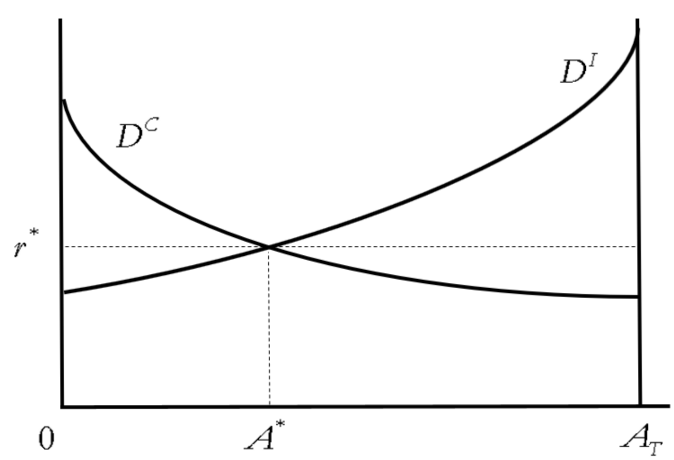

Figure 1. Equilibrium in the perfectly competitive land rental market

In case when transaction costs are positive and the corporate farms possess market power, problem (8) changes to

$$\begin{gathered}\max \Pi^I = p_y f^I\left(A^I, K^I, L^I, M^I\right) - (r+t) A^I - hK^I - wL^I - mM^I \\ \max \Pi^C = p_y f^C\left(A^C, K^C, L^C, M^C\right) - r\left(A^C\right) A^C - hK^C - wL^C - mM^C \\ s.t.\ A^I + A^C = A_T\end{gathered} \tag{9}$$

The first order conditions for (9) are as follows:

$$p_y \frac{\partial f^I}{\partial A^I} = r + t, \tag{10}$$

$$p_y \frac{\partial f^I}{\partial A^I} = \frac{\partial r}{\partial A^C} A^C + r, \tag{11}$$

where the left hand side of (11) represents the marginal benefit (MB) and the right hand side represents the marginal cost (MC) of land for the corporate farms (Ciaian and Swinnen, 2006). The corporate farms choose the amount of land A_t^M where MB equal MC. The rest of the land is allocated to the individual farms, and the rental price in the market r_t^M becomes lower that the competitive price r^*. This situation is graphically depicted in Fig. 2, where D_t^I is the derived demand for land of individual farms in presence of transaction costs t and MC is the marginal cost curve of the corporate farms.

Compared to the case depicted in Fig. 1, corporate farms benefit by enjoying more land at a lower rent, individual farms lose by having less land at a higher cost (the rent in the market is lower but they incur transaction costs), and the landowners lose because of the lower rent in the market.

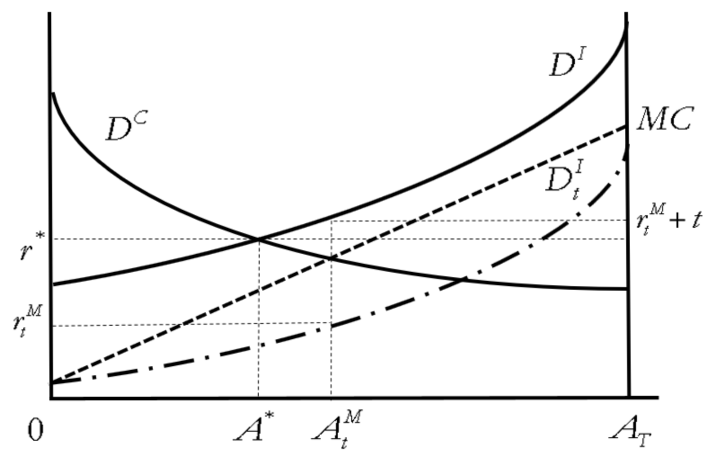

Figure 2. Equilibrium in the imperfect land rental market

Imposing land holdings restrictions on the corporate farms $\overline{A}^C = A^*$ can be used to force the social planner's optimal land distribution in the market. This case is presented in Fig. 3. However, the rent in the market will fall even more to $\overline{r}_t^M$, hurting the landowners who rent the land out.

Moreover, the total welfare losses in the economy after imposing restriction $\bar{A}^C$ would amount to $\left(A_T - \bar{A}^C\right)\cdot\left(r^* - \bar{r}_t^M\right) \equiv \left(A_T - A^*\right)t$. An immediate implication of this analysis is that in order to mitigate market imperfections in the land rental market, imposing land holdings restrictions is not sufficient and should be accompanied by reducing transaction costs.

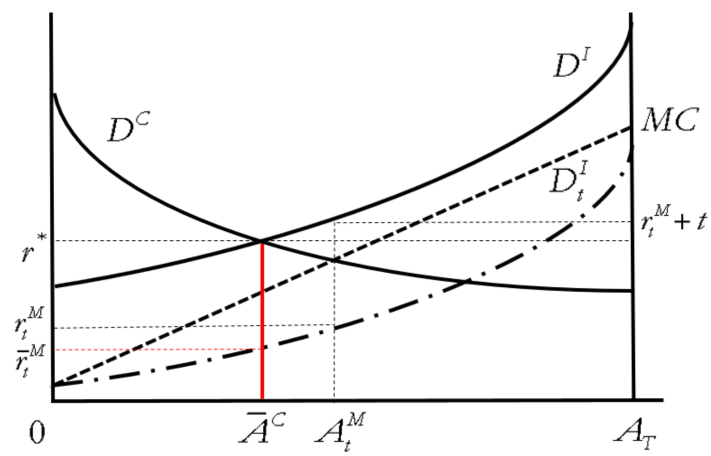

Figure 3. Imposing land holdings restrictions in the imperfect land rental market with transaction costs

3.2. Optimal Land Holdings Restrictions Calculation

As was established above, in order to achieve the social planner's distribution of land between corporate and individual farms, it is necessary to impose land holdings restrictions on the corporate farms. Therefore, in what follows, we will simplify notation and drop all the superscripts in production and cost function notations, assuming that they relate to corporate farms.

In order to calculate the land holdings restrictions that would force corporate farms to allocate amount of land A^* corresponding to the social planner's optimum, it is expedient to proceed along the following steps:

1. Estimate the production function $f(A,K,L,M)$ of the corporate farms and obtain marginal value product of land $MVP_{it}^{A} = p_y \dfrac{\partial f(A_{it},K_{it},L_{it},M_{it})}{\partial A}$ for each farm *i* in each period t.

2. Estimate the cost function $c(r,rp,h,w,m,Y)$ of the corporate farms, where *rp* are property rent payments, and *Y* is the output. In order to impose competitive market conditions, plug MVP_{it}^{A} in place of r_{it} for each farm i in each period t during the estimation. Using Shepard's lemma, derive from c the optimal amount of land A_{it}^{*} for each farm *i* in each period *t*.

3. For those farms where $A_{it}^{*} < A_{it}$, calculate relative land reduction $R_{it} = (A_{it} - A_{it}^{*}) / A_{it}$. Obtain average relative land reduction for each region *j* and each period t $\overline{R}_{jt} = \sum_{i \in J} R_{it} \Big/ |J|$, where *J* is the index set of farms from the data sample operating in region *j*. Average $\overline{R}_{jt}$ for a certain number of years (e.g., last three years available in the sample) to get $\overline{R}_{j}$ and obtain land holdings restrictions for each region as $\overline{A}_{jt} = \overline{R}_{j} \cdot A_{jt}$, where A_{jt} is the amount of land cultivated by corporate farms in region *j* in some period t.

3.2.1. Production Function Estimation and Marginal Product Calculation

In this work, we will estimate the production function using the stochastic frontier model that accounts both for statistical noise and technical efficiencies (TE) (Aigner et al. 1977). The functional from of the production function in this thesis is the transcendental logarithmic function with non-neutral and non-constant technological change (Henningsen, 2019):

$$\begin{gathered} y_{it} = \beta_0 + \sum_{k=1}^{5} \beta_k x_{it}^{(k)} + \frac{1}{2} \sum_{k=1}^{5} \sum_{l=1}^{5} \beta_{kl} x_{it}^{(k)} x_{it}^{(l)} + \\ + \boldsymbol{\beta}_{\mathbf{R}}^T \mathbf{R}_{it} + \boldsymbol{\beta}_{\mathbf{C}}^T \mathbf{C}_{it} + \boldsymbol{\beta}_{\mathbf{D}}^T \mathbf{D}_{it} - u_{it} + v_{it}, \end{gathered} \tag{12}$$

where $y_{it} = \ln Y_{it}$, $x_{it}^{(1)} \equiv \ln A_{it}$, $x_{it}^{(2)} \equiv \ln K_{it}$, $x_{it}^{(3)} \equiv \ln L_{it}$, $x_{it}^{(4)} \equiv \ln M_{it}$ (all the logarithms are demeaned); $x_{it}^{(5)} \equiv T_{it}$ is the mean-adjusted year variable; $\mathbf{R}_{it}$ is the vector of regional dummies controlling for regional differences in agricultural production; $\mathbf{C}_{it}$ is the vector of variables controlling for farm specialization ($C_{it}^{(1)}$ is the share of perennial crop revenues in the output, $C_{it}^{(2)}$ is the share of annual crop revenues in the output); $\mathbf{D}_{it}$ is the vector of dummies controlling for zero inputs; $u_{it} \sim N^+\left(0, \sigma_u^2\right)$ is the half-normally distributed inefficiency term; $v_{it} \sim N\left(0, \sigma_v^2\right)$ is the normally distributed statistical noise.

Marginal products of land MP_{it}^A can be obtained from (12) according to the following formula (Henningsen, 2019):

$$MP_{it}^{A} \equiv \frac{\partial Y_{it}}{\partial A_{it}} = TE_{it} \cdot \alpha_{it} \frac{f}{A_{it}}, \tag{13}$$

where $TE_{it} = e^{-u_{it}}$ are farm-specific technical efficiencies and $\alpha_{it} \equiv \frac{\partial y_{it}}{\partial \ln A_{it}} = \beta_1 + \beta_{11} \ln A_{it} + \beta_{12} \ln K_{it} + \beta_{13} \ln L_{it} + \beta_{14} \ln M_{it} + \beta_{15} T_{it}$ are farm-specific output elasticities with respect to land.

3.2.2. Cost Function Estimation and Optimal Land Amount Calculation

In this work, we will estimate the cost function using the stochastic frontier model in the transcendental logarithmic functional form with non-neutral and non-constant technological change (Henningsen, 2019):

$$\ln \frac{c_{it}}{m_{it}} = \gamma_0 + \sum_{k=1}^{6} \gamma_k \ln \frac{z_{it}^{(k)}}{m_{it}} + \frac{1}{2} \sum_{k=1}^{6} \sum_{l=1}^{6} \gamma_{kl} \ln \frac{z_{it}^{(k)}}{m_{it}} \ln \frac{z_{it}^{(l)}}{m_{it}} + \\ + \boldsymbol{\gamma}_{\mathbf{R}}^{T} \mathbf{R}_{it} + \boldsymbol{\gamma}_{\mathbf{C}}^{T} \mathbf{C}_{it} + u_{it} + v_{it}, \tag{14}$$

where $c_{it} = \ln TC_{it}$, and TC_{it} are total farm costs; $z_{it}^{(1)} \equiv MVP_{it}^{A}$, $z_{it}^{(2)} \equiv h_{it}$, $z_{it}^{(3)} \equiv rp_{it}$, $z_{it}^{(4)} \equiv w_{it}$, $\frac{z_{it}^{(5)}}{m_{it}} \equiv Y_{it}$; $\ln \frac{z_{it}^{(6)}}{m_{it}} \equiv T_{it}$ is the mean-adjusted year variable, and all the logarithms are demeaned; $\mathbf{R}_{it}$ is the vector of regional dummies; $\mathbf{C}_{it}$

is the vector of variables controlling for farm specialization with the same composition as in (12); $u_{it} \sim N^{+}\left(0, \sigma_u^2\right)$ is the half-normally distributed inefficiency term; $v_{it} \sim N\left(0, \sigma_v^2\right)$ is the normally distributed statistical noise. Dividing by m_{it} in (14) is necessary to impose linear homogeneity in input prices.

According to Shepard's lemma, optimal land amount for each farm *i* in each period *t* can be given by (Henningsen, 2019)

$$A_{it}^{*} \equiv \frac{\partial TC_{it}}{\partial MVP_{it}^{A}} = \frac{\partial c_{it}}{\partial \ln MVP_{it}^{A}} \frac{TC_{it}}{MVP_{it}^{A}} = CE_{it} \cdot s_{it} \frac{TC_{it}}{MVP_{it}^{A}}, \qquad (15)$$

where $CE_{it} = e^{u_{it}}$ are farm-specific cost efficiencies and $s_{it} \equiv \frac{MVP_{it}^{A} A_{it}^{*}}{TC_{it}} = \gamma_1^{*} + \gamma_{11}^{*} \ln MVP_{it}^{A} + \gamma_{12}^{*} \ln h_{it} + \gamma_{13}^{*} \ln rp_{it} + \gamma_{14}^{*} \ln w_{it} + \gamma_{15}^{*} \ln m_{it} + $ $+\gamma_{16}^{*} y_{it} + \gamma_{17}^{*} T_{it}$ are farm-specific shares of expenditures on land in the total farm costs, where coefficients γ_1^{*} and γ_{1j}^{*}, $j = 1,...,7$ are related to coefficients from (15) in the following way: $\gamma_1^{*} = \gamma_1$; $\gamma_{1j}^{*} = \gamma_{1j}$, $j = 1,...,4$; $\gamma_{15}^{*} = -\sum_{j=1}^{4} \gamma_{1j}$; $\gamma_{1j}^{*} = \gamma_{1j-1}$, $j = 6,7$.

Chapter 4

DATA DESCRIPTION

4.1. Description of the 50 SG Form Data

For the thesis, we took the farm-level accounting data for 2007–2014 years elicited from the 50 SG forms provided by the State Statistics Service of Ukraine. These data represent an unbalanced panel with information about 14,066 unique corporate agricultural enterprises, making a total of 72,364 observations.

A number of variables from the form were selected for the analysis, and Tables 1 and 2 provides the correspondence between the variables in the form and the variables introduced in Chapter 3.

4.2. Data Cleaning

Before proceeding to the production function estimation, the data from the 50 SG form were preprocessed according to the following procedure:

1. Individual farms were removed from the dataset (enterprises with code 110 according to the State Classifier of Ukraine ДК 002:2004).
2. Farms with non-positive total revenues, labor, expenditures on labor, land, revenues obtained from crop production, and material costs were removed from the dataset.

Table 1. Variables used in production function estimation

Variable from the analysis	Variable from the 50 SG form	Comments
Total revenue Y	Total net revenue obtained from selling crop, livestock, and services	Monetary variable as a proxy for physical output as the latter is unavailable
Land rented A	Total arable land used in production	
Capital K	Sum of depreciation of machinery used in crop and livestock production	Proxy for capital as the latter is unavailable
Labor L	Number of employees working in crop and livestock production	
Materials used M	Sum of expenses on feed, seeds, fertilizers, energy, fuel, spare parts, and oil used in crop and livestock production	Monetary variable as a proxy for physical input as the latter is unavailable
Share of perennial crop revenues in output $C^{(1)}$	Sum of revenues obtained from growing grains, sunflower, soybeans, rape, flax, sugar beets, vegetables, and silage divided by total revenues	
Share of annual crop revenues in output $C^{(2)}$	Sum of revenues obtained from growing fruits, grapes, and hop divided by total revenues	

3. Farms whose revenues per ha, total amount of land calculated, labor, or total costs lie above 99th percentile of corresponding distributions were removed from the dataset.

Table 2. Data description for the variables used in cost function estimation

Variable from the analysis	Variable from the 50 SG form	Comments
Total cost TC	Total cost of producing crop and livestock	
Price of unit of capital h	Sum of depreciation of machinery used in crop and livestock production	Proxy for exogenous input price as the latter is unavailable
Unit property rent payment rp	Total rental payments for property units	Proxy for exogenous input price as the latter is unavailable
Wages w	Sum of the wages and social security transfers for employees working in crop and livestock production divided by labor L	
Average per unit price of materials m	Sum of expenses on feed, seeds, fertilizers, energy, fuel, spare parts, and oil used in crop and livestock production	Proxy for exogenous input price as the latter is unavailable

4. All the monetary values were deflated using the deflators given in Appendix A.

Some descriptive statistics for the dataset after the above processing procedure are given in Table 3.

Table 3. Descriptive statistics for the variables selected for analysis

Variable	Mean	Standard Deviation	Minimum	Maximum
Total revenue Y, UAH	2,711,405	3,785,514	56	103,128,960
Land rented A, ha	1,690	1,662.645	2	14,033
Capital K (proxy), UAH	191,872	1,333,953	0	308,124,646
Labor L	46.780	53.434	1	347
Materials used M (proxy), UAH	1,345,976	3,123,150	56	620,176,501
Share of perennial crop revenues in output $C^{(1)}$, %	0.796	0.277	0.000	1.000
Share of annual crop revenues in output $C^{(2)}$, %	0.016	0.102	0.000	1.000
Total cost TC, UAH	2,665,270	3,353,687	0	22,240,891
Wages w, UAH	5,183	30,082.4	7	7,098,093

4.3. Current Land Distribution in Ukraine

In this work, the last step of the analysis outlined in Sect. 3.2 was applied to the publicly available data on land being cultivated by corporate farms in Ukraine in 2016 as the most recent ones. Figure 4 presents the regional distribution of shares of arable land cultivated by the corporate farms. The distribution was calculated by the author based on the raw data given in Appendix B.

As can be seen in Fig. 4, corporate farms cultivate more than half of the arable land available in eight regions of Ukraine, whereas only three regions have less than 30% of arable land allocated to corporate farms. This is evidence for certain market power corporate farms possess in a number of regional land markets.

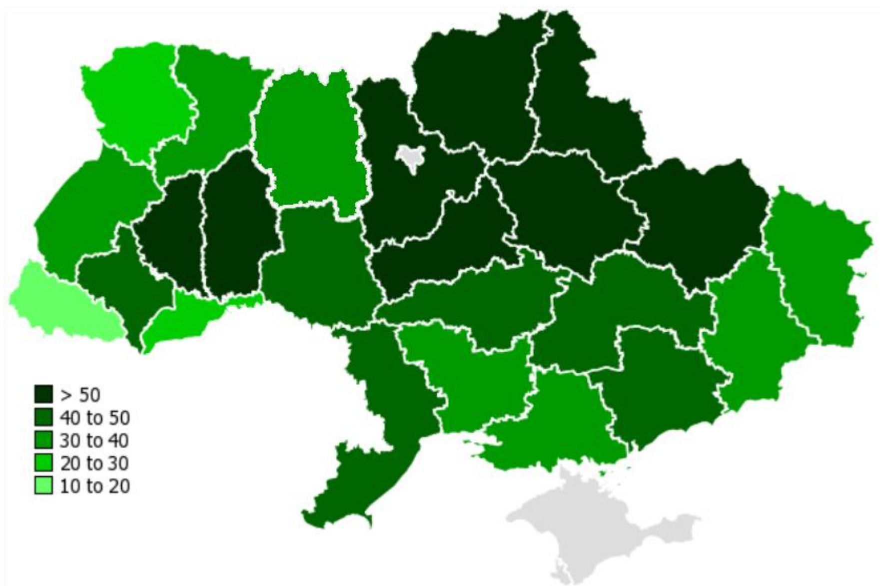

Figure 4. Share of arable land cultivated by the corporate farms in each region of Ukraine in 2016

Chapter 5

RESULTS

Production and cost functions in this thesis were estimated according to specifications (12) and (14), respectively, using `frontier` package in R (Coelli and Henningsen, 2013). The full set of coefficients and corresponding standard errors is given in Appendix C.

Table 4 presents distribution of mean TE of the corporate farms over the years along with corresponding shares of those firms for whom MVP turned out to be higher than the per ha rental payment reported in the 50 SG form. As we can see, over the years, the market power of the corporate farms significantly increased, whereas the TE stayed at almost the same level of around 89.5%.

Table 4. Mean technical efficiencies and shares of farms with undervalued land

Year	2007	2008	2009	2010	2011	2012	2013	2014
Mean TE	0.896	0.895	0.895	0.895	0.894	0.894	0.894	0.895
Share of farms with $MVP > r$, %	53.069	68.601	76.736	78.333	80.812	78.508	79.475	85.092

Using (15) with the estimated coefficients of the cost function, relative reductions R_{jt} were calculated for each region j except for Crimea and Sevastopol (since the data for 2016 are unavailable for these two regions), and Kyiv (as the enterprises registered their obviously don't cultivate the land located in the city) and each year $t = 2007, ..., 2014$ (Appendix D). Average relative reductions $\bar{R}_j$ for each region *j* were obtained by averaging relative reductions for years 2012, 2013, and 2014 and are given in Table 5 along with amount of land currently cultivated by the corporate farms and the maximally allowed amount after imposing land holdings restrictions $\bar{A}_{j,2016}$, both in absolute and relative terms. For convenience, shares of the arable land maximally allowed to be cultivated by the corporate farms after imposing land holdings restrictions is illustrated in Fig. 5.

According to the figure, after imposing appropriate restrictions, concentration of arable land in the hands of corporate farms is expected to be sufficiently reduced. For instance, in the Kyiv region, the region with the highest share of the arable land cultivated by the corporate farms (67.59%), the maximally allowed amount of land after imposing the land holdings restrictions should drop to mere 29.14% of the total arable land in the region.

Percentage point (p.p.) reductions in the arable land cultivated by the corporate farms before and after imposing proposed land holdings restrictions are visualized in Fig. 6. For instance, in the Kyiv region mentioned above, reduction from 67.59% to 29.14% of the total land translates into 38.45 p.p. reduction. Sufficient variation in these values among the regions (possible arising due to the differences in conditions for agricultural production in different parts of Ukraine) suggests that the land holdings restrictions should be imposed on at least per region basis.

Table 5. Average relative reductions $\bar{R}_j$ and land holdings restrictions $\bar{A}_{j,2016}$ (without Crimea, Kyiv, and Sevastopol)

Code[1]	Region	$\bar{R}_j$	Land Cultivated Before Restrictions		Land Cultivated After Restrictions	
			Land, thsd ha	Share of Arable Land, %	Land, thsd ha	Share of Arable Land, %
05	Vinnytska oblast	0.585	849.1	49.11	352.4	20.38
07	Volynska oblast	0.400	179.9	26.75	108.0	16.05
12	Dnipropetrovska oblast	0.629	858.9	40.38	318.6	14.98
14	Donetska oblast	0.596	551.0	33.34	222.8	13.48
18	Zhytomyrska oblast	0.478	442.2	39.74	230.6	20.73
21	Zakarpatska oblast	0.375	21.6	10.78	13.4	6.74
23	Zaporizka oblast	0.604	835.0	43.86	330.6	17.37
26	Ivano-Frankivska oblast	0.552	176.0	44.34	78.8	19.85
32	Kyivska oblast	0.568	913.5	67.59	393.9	29.14
35	Kirovohradska oblast	0.655	807.8	45.78	279.0	15.81
44	Luhanska oblast	0.592	438.0	34.31	178.6	13.99
46	Lvivska oblast	0.463	300.8	37.85	161.6	20.33
48	Mykolaiivska oblast	0.618	633.3	37.27	242.0	14.24
51	Odeska oblast	0.595	932.0	44.90	377.4	18.18
53	Poltavska oblast	0.578	992.3	55.91	419.1	23.62
56	Rivnenska oblast	0.458	216.6	32.92	117.4	17.84
59	Sumska oblast	0.591	714.9	58.30	292.3	23.84
61	Ternopilska oblast	0.550	445.3	52.00	200.5	23.41
63	Kharkivska oblast	0.630	968.5	50.12	357.9	18.52
65	Khersonska oblast	0.570	677.1	38.18	291.4	16.43
68	Khmelnytska oblast	0.566	674.1	53.81	292.4	23.34
71	Cherkaska oblast	0.576	784.5	61.68	332.6	26.15

TABLE 5 — Continued

Code[1]	Region	$\bar{R}_j$	Land Cultivated Before Restrictions: Land, thsd ha	Land Cultivated Before Restrictions: Share of Arable Land, %	Land Cultivated After Restrictions: Land, thsd ha	Land Cultivated After Restrictions: Share of Arable Land, %
73	Chernivetska oblast	0.588	88.0	26.61	36.2	10.95
74	Chernihivska oblast	0.490	888.4	62.60	453.4	31.94

Note: 1) code corresponds to the first two number of the 10-digit code according to the State Classifier of Objects of Administrative and Territorial Structure of Ukraine ДК 014-97.

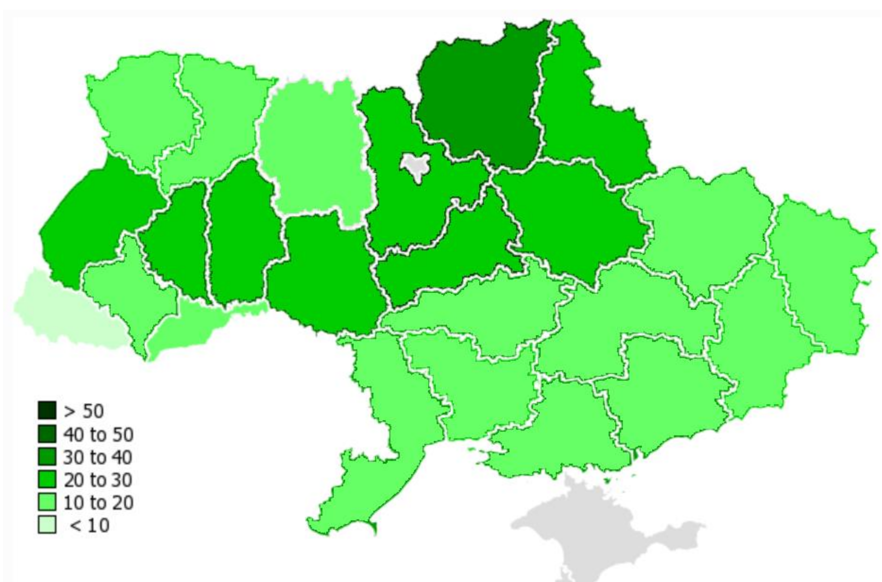

Figure 5. Share of arable land allowed to be cultivated by the corporate farms in each region of Ukraine after imposing land holdings restrictions

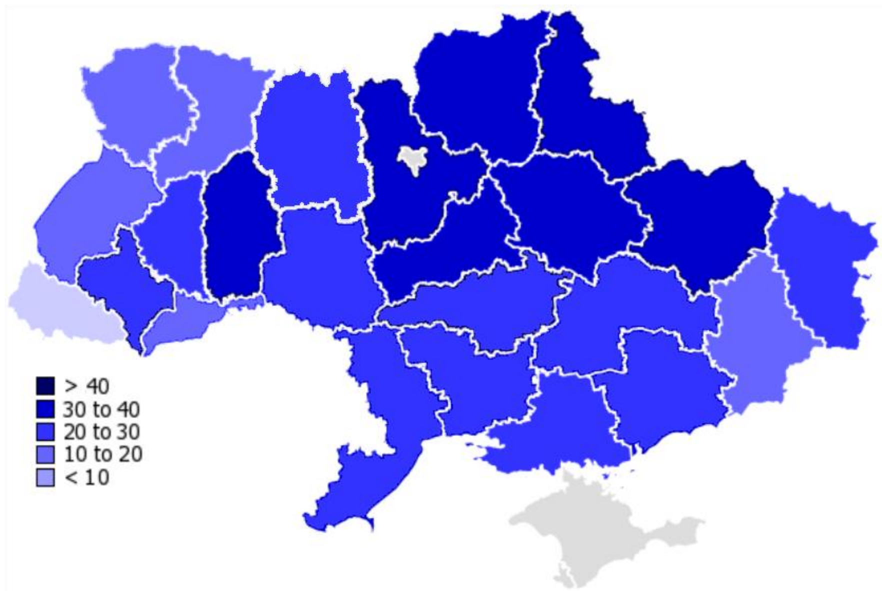

Figure 6. Percentage point reductions in arable land cultivated by the corporate farms in each region of Ukraine before and after imposing land holdings restrictions

Using the data on land holdings restrictions, it is possible to use insights from Sect. 3.1 to estimate the welfare losses of transaction costs borne by individual farmers. To that end, we multiplied the estimated value of the transaction costs equal to 107 UAH/ha according to Hrab (2016) by the total number of land cultivated by individual farmers after imposing the land holdings restrictions, assuming that the land currently cultivated by the corporate farms flows to them. As a result, we can conclude that the imposition of the land holdings restrictions without reducing transaction costs would amount to welfare losses of 1,348.7 mln UAH in 2016 prices.

Chapter 6

CONCLUSIONS

In this thesis, it has been argued that allocative inefficiency evident in the land market in Ukraine can be mitigated with the help of such a policy design option as land holdings restrictions. Using the longitudinal data spanning years from 2007 to 2014, the industry cost function was estimated using marginal value products of land as the true costs that would be borne by economic agents in the competitive land market. Optimal amounts of arable land obtained for each farm in the panel enabled us to calculate the land holdings restrictions for each region of Ukraine in the form of the maximum amount of land allowed to be cultivated by the corporate farms.

After imposing the land holdings restrictions, the total amount of arable land cultivated by the corporate farms would fall from 14,388.8 to 6,080.9 thsd ha. In some regions, the share of arable land cultivated by the corporate farms is expected to fall from over 60% to less than 30% of the total arable land in the region. Values of these restrictions for each region can be used by policy makers to make informed decisions about the per farm restrictions in order to limit the market power of large corporate farms and facilitate the socially optimal land distribution between large and small agricultural enterprises.

At the same time, as was suggested in Chapter 3, imposing land holdings restrictions alone would not be sufficient to improve welfare in the economy, as it would likely lead to reduction of land rent in the market and thereby hurt landowners renting the land out. Therefore, any policy involving land holdings restrictions should encompass reduction of transaction costs in the market as well, e.g. by employing such measures as improving land governance, increasing tenure rights protection, reducing administrative costs related to land transfers (notary fees, taxes, etc.), filling the cadaster with correct information on land parcels and their owners, and other measures. Imposition of the land holdings restrictions without taking mentioned steps would amount to welfare losses of around 1,348.7 mln UAH (in 2016 prices).

Variation in figures for land holdings restrictions among regions of Ukraine suggests that it would be a wise move to delegate the power of establishing appropriate restrictions, or modifying the default values proposed by the law, to the regional councils. In this way, regional differences in conditions for agricultural production can be accounted for, and goes in line with the current decentralization efforts undertaken in Ukraine.

When bringing the policy outlined in the thesis to life, several implementation issues need to be addressed by the policy makers. First, there is an evidence and need to impose and enforce antitrust and competition policies. In particular, competition agencies of Ukraine should pay close attention to several outstanding cases (should they be recorded) when one farm's land plot spans across more than one region, which potentially puts it in the beneficial position relative to the farm with the similar characteristics but operating fully within the borders of a single region. Also, the cases when big enterprises are being artificial split into several smaller ones in order to allocate more land in one hands should be recognized and acted upon. Therefore, ability to trace the legal entities to the end beneficiary becomes one of the cornerstones of successful implementation of the proposed initiatives, or else the regulations will be circumvented, and economic effect would be mediocre if not negative.

Second, the state body responsible for enforcing the land holdings restrictions should meticulously go about calculating true amount of land cultivated by a single farm. In the forms filed to the State Statistics Service of Ukraine, farms report the address of official legal registration, which in some cases (albeit relatively rare ones) does not correspond to the true geographical location of the land plots actually being cultivated. Tracing the actual land parcels to the legal entity responsible for cultivating it puts additional pressure on the authorities, but the task is not insurmountable in principle.

Finally, potential corruption risks stemming from increased discretionary power of the regional councils should not be overlooked, and appropriate law enforcement agencies should be closely monitoring the decisions of the local governments. These issues would be especially important for the regions where market concentration is the highest at the time the new policy is being introduced.

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APPENDIX A

DEFLATORS

Table 6. Values used to deflate monetary variables in the thesis

Year	Crop[1]	Live-stock[2]	Electri-city[3]	Fuel[4]	Fertili-zers[5]	Machines[6]	Wage[7]	CPI[8]
2004	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2005	0.955	1.295	1.131	1.033	1.109	1.097	1.056	1.240
2006	1.090	1.150	1.396	1.130	1.217	1.209	1.119	1.583
2007	1.718	1.332	1.687	1.700	1.477	1.418	1.253	2.017
2008	1.636	1.963	2.399	1.435	1.856	1.775	1.528	2.627
2009	1.785	1.990	2.493	2.050	2.369	2.162	1.646	2.743
2010	2.495	2.275	2.805	2.564	2.741	2.459	1.847	3.041
2011	2.887	2.484	3.394	2.972	3.234	2.842	1.991	3.492
2012	3.049	2.683	3.702	2.755	3.402	2.947	2.001	3.841
2013	2.799	2.747	3.895	2.755	3.222	0.000	1.899	4.105
2014	3.616	3.272	5.005	3.882	4.959	0.000	2.086	4.569

Notes: 1) used for deflating crop revenues, expenditures on feed and seeds; 2) used for deflating livestock revenues; 3) used for deflating expenditures on electricity; 4) used for deflating expenditures on fuel and oil; 5) used for deflating expenditures on fertilizers; 6) used for deflating depreciation costs and expenditures on spare parts; 7) used for deflating wages and social security transfers; 8) used for deflating all the other variables.

APPENDIX B

LAND DISTRIBUTION IN UKRAINE

Table 7. Agricultural Enterprises and Amount of Land Cultivated in 2016 (without Crimea, Kyiv and Sevastopol)

Code[1]	Region	Enterprises		Arable Land Cultivated, thsd ha	
		Total	Individual Farms	Total	Individual Farms
05	Vinnytska oblast	2,668	1,894	1,094.5	245.4
07	Volynska oblast	909	600	231.6	51.7
12	Dnipropetrovska oblast	4,111	3,194	1,307.9	449.0
14	Donetska oblast	1,326	956	724.6	173.6
18	Zhytomyrska oblast	1,103	586	508.6	66.4
21	Zakarpatska oblast	1,084	939	30.3	8.7
23	Zaporizka oblast	2,790	2,046	1,168.1	333.1
26	Ivano-Frankivska oblast	759	507	203.1	27.1
32	Kyivska oblast	2,212	1,221	1,058.3	144.8
35	Kirovohradska oblast	3,229	2,550	1,221.5	413.7
44	Luhanska oblast	1,062	802	653.1	215.1
46	Lvivska oblast	1,209	788	351.8	51.0
48	Mykolaiivska oblast	4,040	3373	979.2	345.9
51	Odeska oblast	5,107	3,966	1,323.0	391.0
53	Poltavska oblast	2,443	1,804	1,230.9	238.6
56	Rivnenska oblast	629	371	246.3	29.7
59	Sumska oblast	1,089	639	830.2	115.3
61	Ternopilska oblast	1,079	620	511.4	66.1
63	Kharkivska oblast	1,967	1,211	1,227.4	258.9
65	Khersonska oblast	2,644	2,047	938.6	261.5
68	Khmelnytska oblast	1,573	1,095	804.5	130.4
71	Cherkaska oblast	2,000	1,274	930.9	146.4

TABLE 7 — Continued

Code[1]	Region	Enterprises		Arable Land Cultivated, thsd ha	
		Total	Individual Farms	Total	Individual Farms
73	Chernivetska oblast	832	596	114.0	26.0
74	Chernihivska oblast	1,120	598	995.9	107.5

Source: States Statistics Service of Ukraine, http://www.ukrstat.gov.ua/operativ/operativ2018/sg/ksgp/ksgp_u/ksgp_11_u.htm

Note: 1) code corresponds to the first two number of the 10-digit code according to the State Classifier of Objects of Administrative and Territorial Structure of Ukraine ДК 014-97.

Table 8. Total Amount of Arable Land in 2016 (without Crimea, Kyiv, and Sevastopol)

Code[1]	Region	Arable Land, ha
05	Vinnytska oblast	1,729,125
07	Volynska oblast	672,601
12	Dnipropetrovska oblast	2,127,187
14	Donetska oblast	1,652,803
18	Zhytomyrska oblast	1,112,689
21	Zakarpatska oblast	200,309
23	Zaporizka oblast	1,903,577
26	Ivano-Frankivska oblast	396,972
32	Kyivska oblast	1,351,756
35	Kirovohradska oblast	1,764,622
44	Luhanska oblast	1,276,613
46	Lvivska oblast	794,683
48	Mykolaiivska oblast	1,699,158
51	Odeska oblast	2,075,513
53	Poltavska oblast	1,774,687
56	Rivnenska oblast	657,996
59	Sumska oblast	1,226,260
61	Ternopilska oblast	856,413
63	Kharkivska oblast	1,932,361
65	Khersonska oblast	1,773,674
68	Khmelnytska oblast	1,252,718
71	Cherkaska oblast	1,271,860
73	Chernivetska oblast	330,759
74	Chernihivska oblast	1,419,226

Source: Land Governance Monitoring, http://www.kse.org.ua/uk/research-policy/land/governance-monitoring/database-2016-2017/

Note: 1) code corresponds to the first two number of the 10-digit code according to the State Classifier of Objects of Administrative and Territorial Structure of Ukraine ДК 014-97.

APPENDIX C

PRODUCTION AND COST FUNCTION ESTIMATION

Table 9. Production function coefficients

Variable	Coefficient	Variable	Coefficient
Intercept	0.065*** (0.015)	$\ln L$	0.061*** (0.009)
$\ln A$	0.107*** (0.010)	$\ln M$	0.710*** (0.010)
$\ln K$	0.120*** (0.007)	T	0.001* (0.001)
Quadratic Terms			
$\frac{1}{2}\ln^2 A$	0.349*** (0.018)	$\frac{1}{2}\ln^2 M$	–0.063*** (0.017)
$\frac{1}{2}\ln^2 K$	0.066*** (0.009)	$\frac{1}{2}T^2$	–0.001*** (0.000)
$\frac{1}{2}\ln^2 L$	0.035* (0.015)		
Cross-Interaction Terms			
$\ln A \cdot \ln K$	–0.048*** (0.009)	$\ln K \cdot \ln M$	–0.100*** (0.008)
$\ln A \cdot \ln L$	–0.087*** (0.011)	$\ln K \cdot T$	–0.016*** (0.001)
$\ln A \cdot \ln M$	–0.013 (0.012)	$\ln L \cdot \ln M$	0.005 (0.011)
$\ln A \cdot T$	0.028*** (0.001)	$\ln L \cdot T$	–0.010*** (0.001)
$\ln K \cdot \ln L$	0.081*** (0.007)	$\ln M \cdot T$	0.018*** (0.002)
Control Variables			
R_{01}	–0.071*** (0.015)	R_{48}	–0.016 (0.015)
R_{05}	–0.009 (0.015)	R_{51}	–0.066*** (0.014)
R_{07}	–0.063*** (0.015)	R_{53}	0.036* (0.015)
R_{12}	0.003 (0.015)	R_{56}	–0.026 . (0.016)

TABLE 9 — Continued

Variable	Coefficient	Variable	Coefficient
R_{14}	–0.042**	R_{59}	–0.026 .
	(0.015)		(0.015)
R_{18}	–0.049***	R_{61}	–0.009
	(0.015)		(0.015)
R_{21}	–0.067***	R_{63}	–0.010
	(0.019)		(0.015)
R_{23}	–0.044**	R_{65}	–0.011
	(0.014)		(0.015)
R_{26}	–0.010	R_{68}	–0.006
	(0.017)		(0.015)
R_{31}	–0.138	R_{71}	0.042**
	(0.147)		(0.015)
R_{32}	0.011	R_{73}	–0.024
	(0.014)		(0.017)
R_{35}	0.023	R_{74}	–0.035*
	(0.015)		(0.015)
R_{44}	–0.076***	R_{85}	–0.117**
	(0.015)		(0.042)
R_{46}	–0.010	$C^{(1)}$	0.256***
	(0.016)		(0.010)
$C^{(2)}$	0.063***	D_K	0.000
	(0.004)		(0.003)
Efficiency			
Inefficiency	0.505***		
	(0.007)		

*** p<0.001, ** p<0.01, * p<0.05, . p < 0.1

Table 10. Cost function coefficients

Variable	Coefficient	Variable	Coefficient
Intercept	0.362*** (0.012)	$\ln \frac{w}{m}$	–0.048*** (0.004)
$\ln \frac{MVP}{m}$	0.043*** (0.004)	$\ln Y$	0.010 (0.010)
$\ln \frac{h}{m}$	–0.011** (0.004)	T	0.016*** (0.001)
$\ln \frac{rp}{m}$	0.015* (0.006)		
Quadratic Terms			
$\frac{1}{2}\ln^2 \frac{MVP}{m}$	–0.032*** (0.002)	$\frac{1}{2}\ln^2 \frac{w}{m}$	0.035*** (0.002)
$\frac{1}{2}\ln^2 \frac{h}{m}$	0.112*** (0.003)	$\frac{1}{2}\ln^2 Y$	–0.051*** (0.009)
$\frac{1}{2}\ln^2 \frac{rp}{m}$	–0.018*** (0.004)	$\frac{1}{2}T^2$	0.007*** (0.000)
Cross-Interaction Terms			
$\ln \frac{MVP}{m} \cdot \ln \frac{h}{m}$	0.004* (0.002)	$\ln \frac{h}{m} \cdot T$	–0.006*** (0.001)
$\ln \frac{MVP}{m} \cdot \ln \frac{rp}{m}$	–0.009** (0.003)	$\ln \frac{rp}{m} \cdot \ln \frac{w}{m}$	0.016*** (0.003)
$\ln \frac{MVP}{m} \cdot \ln \frac{w}{m}$	0.033*** (0.002)	$\ln \frac{rp}{m} \cdot \ln Y$	0.024** (0.008)
$\ln \frac{MVP}{m} \cdot \ln Y$	0.035*** (0.005)	$\ln \frac{rp}{m} \cdot T$	–0.002* 0.001
$\ln \frac{MVP}{m} \cdot T$	0.003*** (0.001)	$\ln \frac{w}{m} \cdot \ln Y$	0.243*** (0.007)
$\ln \frac{h}{m} \cdot \ln \frac{rp}{m}$	0.023*** (0.003)	$\ln \frac{w}{m} \cdot T$	–0.007*** (0.001)
$\ln \frac{h}{m} \cdot \ln \frac{w}{m}$	–0.015*** (0.002)	$\ln Y \cdot T$	0.002 . (0.001)
$\ln \frac{h}{m} \cdot \ln Y$	–0.002 (0.005)		

TABLE 10 — Continued

Variable	Coefficient	Variable	Coefficient
Control Variables			
R_{01}	0.002	R_{48}	–0.019
	(0.012)		(0.011)
R_{05}	–0.002	R_{51}	–0.017
	(0.011)		(0.011)
R_{07}	0.017	R_{53}	0.030**
	(0.012)		(0.011)
R_{12}	–0.031**	R_{56}	0.022 .
	(0.011)		(0.012)
R_{14}	–0.001	R_{59}	0.023 *
	(0.012)		(0.012)
R_{18}	0.029*	R_{61}	–0.010
	(0.012)		(0.012)
R_{21}	–0.014	R_{63}	–0.010
	(0.015)		(0.011)
R_{23}	0.003	R_{65}	0.015
	(0.011)		(0.012)
R_{26}	–0.032*	R_{68}	0.006
	(0.013)		(0.012)
R_{31}	–0.097	R_{71}	0.021 .
	(0.146)		(0.011)
R_{32}	0.018	R_{73}	0.030*
	(0.011)		(0.013)
R_{35}	–0.013	R_{74}	0.035**
	(0.011)		(0.011)
R_{44}	–0.026*	R_{85}	–0.133**
	(0.012)		(0.041)
R_{46}	–0.014	$C^{(1)}$	0.196***
	(0.012)		(0.008)
$C^{(2)}$	0.039***		
	(0.003)		
Efficiency			
Inefficiency	0.791***		
	(0.004)		

*** p<0.001, ** p<0.01, * p<0.05, . p < 0.1

APPENDIX D

RELATIVE REDUCTIONS IN LAND HOLDINGS

Table 11. Relative reductions R_{jt} (without Crimea, Kyiv, and Sevastopol)

Region \ Year	2007	2008	2009	2010	2011	2012	2013	2014
Vinnytska oblast	0.29	0.43	0.58	0.53	0.51	0.58	0.57	0.60
Volynska oblast	0.03	0.09	0.21	0.27	0.29	0.32	0.41	0.47
Dnipropetrovska oblast	0.50	0.54	0.64	0.61	0.57	0.63	0.62	0.64
Donetska oblast	0.36	0.43	0.59	0.56	0.49	0.57	0.58	0.64
Zhytomyrska oblast	0.07	0.16	0.26	0.30	0.35	0.42	0.47	0.54
Zakarpatska oblast	0.05	0.03	0.21	0.24	0.21	0.31	0.43	0.39
Zaporizka oblast	0.49	0.54	0.66	0.63	0.55	0.60	0.60	0.61
Ivano-Frankivska oblast	0.08	0.28	0.40	0.37	0.34	0.51	0.57	0.58
Kyivska oblast	0.23	0.32	0.47	0.44	0.47	0.55	0.57	0.59
Kirovohradska oblast	0.52	0.58	0.69	0.67	0.60	0.66	0.63	0.67
Luhanska oblast	0.46	0.43	0.57	0.56	0.50	0.60	0.56	0.62
Lvivska oblast	0.08	0.17	0.25	0.29	0.33	0.37	0.49	0.53
Mykolaiivska oblast	0.43	0.51	0.64	0.59	0.56	0.62	0.61	0.63
Odeska oblast	0.43	0.55	0.59	0.55	0.52	0.55	0.61	0.62
Poltavska oblast	0.43	0.45	0.61	0.55	0.52	0.58	0.58	0.57
Rivnenska oblast	0.13	0.24	0.30	0.37	0.38	0.38	0.49	0.51
Sumska oblast	0.32	0.38	0.53	0.50	0.50	0.58	0.57	0.62
Ternopilska oblast	0.19	0.36	0.50	0.41	0.45	0.53	0.55	0.57
Kharkivska oblast	0.47	0.49	0.63	0.58	0.56	0.64	0.61	0.64
Khersonska oblast	0.42	0.52	0.59	0.52	0.50	0.57	0.56	0.58
Khmelnytska oblast	0.18	0.34	0.43	0.46	0.44	0.52	0.56	0.62
Cherkaska oblast	0.32	0.42	0.59	0.52	0.50	0.60	0.55	0.57
Chernivetska oblast	0.09	0.25	0.39	0.38	0.43	0.53	0.59	0.64
Chernihivska oblast	0.18	0.21	0.36	0.35	0.38	0.45	0.49	0.53