Land market distortions: Theory and evidence from Guatemala*

Manuel A. Hernandez Miguel Robles Danilo Trupkin

[Preliminary and incomplete]

Abstract

Farm size and land allocation are important factors in explaining lagging agricultural productivity in developing countries. This paper formally examines the effect of land market distortions on the allocation of land across farmers and overall agricultural productivity. We first develop a theoretical framework to model the optimal size distribution of farms and to determine to what extent market distortions can explain the non-optimal allocation of land. We then calibrate the model to the case of Guatemala and evaluate potential drivers of the distortions across regions. Preliminary results find that the aggregate agricultural productivity is 75-80% of the efficient output. We discuss alternative policy implications to improve land markets efficiency.

Keywords: Land markets, distortions, agricultural productivity, Guatemala

JEL Classifications: O13, O40, Q15

*We thank the Instituto Nacional de Estadistica (INE) and the Secretaria de Seguridad Alimentaria y Nutricional (SESAN) of Guatemala for their help in accessing and collecting part of the data used in the analysis. Francisco Ceballos and Braulio Britos provided excellent research assistance. The authors gratefully acknowledge financial support from IFPRI. All errors are our own. Contact information: Hernandez: IFPRI, m.a.hernandez@cgiar.org; Robles: The World Bank, lmrobles@worldbank.org; Trupkin: IIEP-Universidad de Buenos Aires, danilo.trupkin@fce.uba.ar.

1 Introduction

It is well established that agriculture plays a key role in explaining the large disparities in labor productivity between developing and developed countries (Caselli; Restuccia et al., 2008; Lagakos and Waugh, 2013). Poor countries employ most of their workers in agriculture and are much more unproductive than rich countries. As noted by Adamopolous and Restuccia (2014) (hereafter AR), farm size and land allocation are important factors in explaining this lagging agricultural productivity in poor countries; there are important differences in the size distribution of farms between rich and poor countries with a considerably smaller operational scale of farms in poor countries, and with large farms having a significantly higher labor productivity than smaller ones. Further understanding farm size patterns, the allocation of land through markets and the drivers of these processes is critical to reduce the agricultural productivity gap in developing countries.

The objective of this study is twofold. First, formally assess the impact of land market distortions on the allocation of land across farmers and on agricultural productivity. Second, quantify the magnitude of these distortions using as an example the case of Guatemala and examine potential drivers of these distortions exploiting differences across regions. Ultimately, the study intends to discuss alternative policies to improve efficiency in land markets through the reduction of market frictions.

The remainder of the paper is structured as follows. Section 2 presents the theoretical model and its implications. Section 3 describes the data and a set of empirical facts. Section 4 calibrates the model to the case of Guatemala and discusses the quantitative results. Section 5 concludes.

2 Model

We develop a two-sector model of agriculture and non-agriculture featuring endogenous distributions of both farm size and location. The model follows AR, except that we introduce a location dimension and abstract from the capital decision. In each period the economy produces two consumption goods: an agricultural good (a) and a non-agricultural good

(n). We focus on the agricultural sector and assume that the technology for producing the non-agricultural good is isomorphic to the one in AR.

2.1 Farmers

The agricultural good is produced with land by a farmer with managerial skills s. The farm technology is characterized by decreasing returns to scale. In particular, a farmer of type i has the following production function

$$y_{a,i} = s_i l_i^{\alpha},$$

where y_a is the agricultural output of farm i and l is the amount of land. The parameter α captures the land elasticity.

Preferences and endowments are the same as in AR. The economy is endowed with a fixed amount of total land L. We abstract from the selection channel into agriculture by assuming that the productivity of farmers is realized after the sectoral allocation decision (see Lagakos and Waugh, 2013). The household decides what fraction of its members work in the agricultural sector, after which they draw their farmer managerial ability from a known time-invariant distribution with cdf $F(s)$ and pdf $f(s)$, with support $S = [\underline{s}, \overline{s}]$.

Consider a discrete number of N types of farmers with different managerial skills denoted by s_i, for $i = 1, ..., N$, distributed in N regions located across the country. For simplicity, we assume that there is only one type of farmer per region and rank the managerial ability such that $s_1 > s_2 > ... > s_N$. Hence, there are differences in terms of technology across regions.

The households characteristics are the same across regions. More specifically, we assume that households in all regions choose the same fraction of its members, N_a, to work in the agricultural sector.

Without loss of generality, we further assume that the regions (denoted hereafter as r) are located linearly in terms of proximity, such that r_i is the adjacent region (the neighbor) of r_{i+1}, and the subindex i identifies both the region and the managerial ability. Based on the assumption above, r_1 is the most productive region; its neighboring, next closest location r_2 is the second most productive; and so forth. This assumption is not necessary for our purposes, but simplifies the analysis. We discuss below how the results change if we relax this assumption.

Finally, we assume that there is a transaction cost τ for a farmer who demands land across the border, and this cost is increasing with distance. That is, $\tau_{ij} = \tau(d_{i,j})$, with $\tau_{ii} = 0$ and $\tau'(\cdot) > 0$, where $d_{i,j}$ is defined as the distance between region i and j. These costs can be justified in several ways. They can be interpreted as the difficulties faced by farmers who demand land in other markets where information is weaker for newcomers (and the lack of information increases with distance), the existence of asymmetries in the form of certain (market) power for insiders, and transportation costs for implementing effective managerial control, among other factors. These imperfections result in misallocations in the land market. Below we quantify the role that these failures play in terms of welfare losses.

2.2 Competitive Equilibrium

The firm's problem in the agricultural sector is defined as follows.[1] A farmer with managerial ability s_i located in region i maximizes profits by demanding land taking the rental prices of land (q) and the relative price of the agricultural good p_a as given,

$$\max_{\{l_{ij}\}_{j=1}^{N}} \pi(s_i) = \left\{ p_a s_{ij} l_{ij}^{\alpha} - \sum_{j=1}^{N} (q_j + \tau_{ij}) l_{ij} \right\}$$

where l_{ij} is the demand for land in market j of a farmer in region i, and $l_i = \sum_{j=1}^{N} l_{ij}$ is the total demand for land of farmer i.

The optimal condition for the i^{th} farmer is

$$\alpha p_a s_{ij} {l_{ij}}^{\alpha-1} = q_j + \tau_{ij} \quad \text{in all markets } j.$$

We abstract from differences in land endowments and assume that the supply of land is the same across regions, i.e., $l_j^s = l^s$ for all $j = 1, ..., N$. The market clearing condition

[1] The firm's problem in non-agriculture is isomorphic to the one in AR.

for land in each region becomes,

$$N_a \sum_{i=1}^{N} l_{ij} = l_j^s = l^s.$$

Further, the aggregate market clearing condition for land is $L = N_a \sum_{i=1}^{N} l_i$. To simplify notation, we define $l \equiv l^s/N_a$. Then, the market clearing condition for each region becomes $\sum_{i=1}^{N} l_{ij} = l$.

To solve for the equilibrium in the land market, we make the following additional assumptions.

Assumption 1: $l_{ii} > 0$ for all i.

There is at least some positive demand for land of a typical farmer in its own region. By assuming this, we avoid the cases in which "foreign" farmers take-over all the land in a region and, at the same time, restricts farmers to only demand land in neighboring regions (i.e. $l_{ij} = 0$ for $|j - i| > 1$).

Assumption 2: Let the equilibrium rental price of region i in autarky be equal to q_i^A (i.e. when no trade is allowed among regions). We assume that $\tau_{ij} < |q_i^A - q_j^A|$ for all i and j.

This assumption implies that there is always some trade between regions (farmers purchasing lands across the border), even under the presence of transaction costs.

Result 1: Given that $s_1 > s_2 > ... > s_N$, then $l_{ij} = 0$ for $j < i$ (i.e. $l_{21} = l_{32} = ... = 0$).

The optimal farm size of less productive farmers will be lower than the optimal farm size of more productive ones. Hence, there is not any equilibrium in which farmers in less productive regions rent land in more productive markets; otherwise, it would not be an optimal allocation.

Given Result 1 and Assumptions 1 and 2, we have a system of $(N-1)$ equations for each land market clearing condition, and $(N-1)$ conditions equating the marginal product of land for all farmers, net of transaction costs,

$$\begin{aligned} l_{11}^* &= l \\ l_{12}^* + l_{22}^* &= l \end{aligned}$$

$$\vdots$$

$$\begin{aligned}
l^*_{(N-1)N} + l^*_{NN} &= l \\
f_{l_1}(l^*_{11} + l^*_{12}) &= f_{l_2}(l^*_{22} + l^*_{23}) + \tau_{12} \\
f_{l_2}(l^*_{22} + l^*_{23}) &= f_{l_3}(l^*_{33} + l^*_{34}) + \tau_{23} \\
&\vdots \\
f_{l_{N-1}}(l^*_{(N-1)(N-1)} + l^*_{(N-1)N}) &= f_{l_N}(l^*_{NN}) + \tau_{(N-1)N}
\end{aligned}$$

where $f_{l_i}(\cdot)$ is farmer i's marginal productivity of land and the function argument identifies farmer $i's$ demand for land in all markets, $l_i = \sum_{j=1}^{N} l_{ij}$. Substituting the set of $(N-1)$ market clearing conditions for land into the $(N-1)$ conditions that equate the marginal productivity of land for all farmers, net of transaction costs, we obtain the following set of equilibrium conditions:

$$f_{l_1}(2l - l^*_{22}) = f_{l_2}(l + l^*_{22} - l^*_{33}) + \tau_{12} \tag{1}$$

$$f_{l_2}(l + l^*_{22} - l^*_{33}) = f_{l_3}(l + l^*_{33} - l^*_{44}) + \tau_{23} \tag{2}$$

$$\vdots$$

$$f_{l_{N-1}}(l + l^*_{(N-2)(N-2)} - l^*_{(N-1)(N-1)}) = f_{l_N}(l^*_{NN}) + \tau_{(N-1)N}. \tag{3}$$

We have a system of $(N-1)$ equations to solve for the $(N-1)$ unknowns l^*_{ii} for $i = 2, ..., N$. We use the set of $(N-1)$ land market clearing conditions to solve for the remaining (cross-region) demands $l^*_{i(i+1)}$ for $i = 1, ..., N-1$.

The whole system can be easily solved as follows. First, from equation (1), we solve for l^*_{33} as a function of l^*_{22}. In equation (2), we plug l^*_{33} in terms of l^*_{22} and obtain an expression for l^*_{44} as a function of l^*_{22}. We proceed in sequential order to obtain an expression for l^*_{NN} in terms of l^*_{22}, i.e. $l^*_{NN}(l^*_{22})$. Since $f_{l_N}[l^*_{NN}(l^*_{22})] = f_{l_1}(2l - l^*_{22}) - \sum_{j=1}^{N-1} \tau_{jN}$, we obtain a solution for l^*_{22} and, then, for the remaining unknowns.

Finally, we obtain the set of N equlibrium prices, q^*_j, as follows,

$$\begin{aligned}
q^*_1 &= f_{l_1}(l + l^*_{12}) \\
q^*_2 &= q^*_1 - \tau_{12}
\end{aligned}$$

$$
\begin{aligned}
q_3^* &= q_2^* - \tau_{23} \\
&\vdots \\
q_N^* &= q_{N-1}^* - \tau_{(N-1)N}.
\end{aligned}
$$

2.3 A Simple Example

Consider two types of farmers, two regions, and the technology for producing the agricultural good defined above as $y_a = s_i l_i^{\alpha}$.

Let $s_1 > s_2$. Then, the two equilibrium conditions to solve for l_{12}^* and l_{22}^* are the following,[2]

$$
\begin{aligned}
\alpha s_1 (l + l_{12}^*)^{\alpha-1} &= \alpha s_2 (l_{22}^*)^{\alpha-1} + \tau_{12} \\
l_{12}^* + l_{22}^* &= l,
\end{aligned}
$$

which implies a unique equation to solve for l_{22}^*,

$$
\alpha s_1 (2l - l_{22}^*)^{\alpha-1} = \alpha s_2 (l_{22}^*)^{\alpha-1} + \tau_{12}.
$$

Once obtained l_{22}^*, we solve for $l_{12}^* = l - l_{22}^*$.

Consider the following parameter values:

α	s_1	s_2	l	τ_{12}
0.5	2	1	1	0.2

Then, the optimal allocation is equal to,

l_{11}^*	l_{12}^*	l_{21}^*	l_{22}^*	q_1^*	q_2^*
1	0.4	0	0.6	0.85	0.65

We observe that the typical farmer in Region 1 (the more productive one) captures the whole land in its market, plus the 40% of land in Region 2 (where the less productive farmer is located).

This result allows us to characterize both farm size and location, and quantify the distortions. For instance, if $\tau_{12} = 0$ (i.e. there are no transaction costs/distorsions), we obtain the following result,

[2]Remember that an optimal allocation imples $l_{11}^* = l$ and l_{21}^*=0.

l_{11}^*	l_{12}^*	l_{21}^*	l_{22}^*	q_1^*	q_2^*
1	0.6	0	0.4	0.79	0.79

Thus, the typical farmer in Region 1 captures the 60% of land in Region 2 in addition to the whole land in her market. See Figure 1 for further details.

3 The Case of Guatemala

This section describes the context of land markets in Guatemala. We rely on a number of alternative data sources that allow us to explore some empirical regularities. We first present the data sources used.

3.1 Data

We rely on three different data sources. We use micro-data from the "IV Censo Nacional Agropecuario 2003" corresponding to the crop year 2002-03. The census is nationally representative and includes information on land use (for crops, cattle farming and other activities), production, input use and land quality variables, farmers' socioeconomic characteristics, among others. We also use data from a three-year panel survey of households collected between 2012 and 2014 as part of the monitoring and evaluation of the Zero Hunger Pact, a massive program executed by the Government of Guatemala against malnutrition. The surveys were administered to urban and rural households in more than half of the administrative areas (known as municipalities) in the country with the highest rates of child malnutrition.[3] These surveys included a module on agricultural land markets that inquired about land prices, past transactions and general perceptions on the development of local land markets. Finally, we use income indices at the department level from the "National Human Development Report 2005" produced by the United Nations Development Programme.

[3]Guatemala is divided into 22 departaments and 340 municipalities. The survey covered 176 municipalities.

3.2 Land Markets in Guatemala

Guatemala is an interesting case study for analysis as it exhibits a large degree of heterogeneity in terms of climate, geography, ethnic composition and regional development. While agricultural activity in some regions is characterized by large-scale commercial farming of export crops, such as sugar cane, palm and tobacco, other regions are dominated by smallholder farming, mainly for subsistence purposes.

We begin by providing general descriptive statistics on the size of landholdings using data from the agricultural census. Table 1 shows the size distribution of farms in the country as a whole and disaggregated by region. Overall, small farms (under 1 hectare) represent the majority of farms in Guatemala (almost 60%), while very large farms (over 20 hectares) represent only 3.5% of the farms.[4] The small size of landholdings is a regular pattern in developing countries as opposed to developed countries, where a large share of farms operate under much larger scales. For instance, Restuccia and Santaeulalia-Llopis (2015) report more than 81% and 46% of farms in the United States (US) and Belgium having more than 10 hectares, and only 15% of farms in Belgium having less than one hectare and none in the case of the US. The table also shows a large variation in the distribution of landholding size across regions. In particular, three quarters of the agricultural landholdings in the Western Highlands ('Altiplano Occidental') –the poorest region in terms of economic and human development– are smaller than one hectare. In contrast, the Petén-Izabal region concentrates most of the cattle farming activities of the country and thus exhibits much larger landholdings than the rest of the regions.

The above variability is illustrative of a wide set of factors determining agricultural practices in the country and it is certainly interesting in its own respect. However, since the main purpose of this study is to explore the role of information and transaction costs in the (mis)allocation of land across agents with varying levels of productivity, we abstract in what follows from the complexities of the crop choice decision. We focus instead on the size and level of productivity of agricultural units producing maize and beans, the two

[4] We observe a similar distribution if we consider landholding size used for temporary or permanent crops alone.

most common and extended crops in Guatemala.

To introduce the concept of productivity and provide an overview of its variability across the country, Table 2 shows summary statistics for maize and bean yields, a commonly used agricultural productivity measure. We observe again large differences in both the average levels and the variability of yields across regions. Yet, this level of variability is not necessarily indicative of the presence of land market inefficiencies as it could result from an optimal allocation of production factors. We return to this point in Section 4 below.

Figure 2 shows, in turn, some aggregate patterns for the size of landholdings dedicated to maize and bean production relative to the level of agricultural development of the different departments. As a proxy for the level of agricultural development we use the value of total agricultural production per capita constructed from the census data.[5] The figure shows the average share of very small (under 1 hectare) and very large (over 20 hectares) maize and bean farms by income index quintiles (where Q1 represents the 1/5 of departments with the lowest levels of income). We observe that at lower income levels, the share of very small farms tends to be much higher than at higher income levels. The opposite is true for very large farms, which gain relative importance in departments with higher levels of income. This is in line with the international evidence presented in Adamopolous and Restuccia (2014) and is indicative of the presence of inefficiencies in land markets.

Figure 3 provides additional empirical motivation on the discussion of land market inefficiencies described in Section 2. In the panel collected in more than half of the country between 2012-2014, households were asked to provide the price per hectare of what they would consider to be the most productive agricultural land in their corresponding administrative area (municipality). The purpose of the question was to evaluate the variability in farmers' perceptions about land prices in their immediate geographic area. We thus calculate the coefficient of variation for this price across all farmer responses within each administrative area and use it as a proxy measure for land market imperfections. Figure 3 shows a scatterplot of the concentration ratio in landholdings (calculated from the

[5]The production is valued using local prices at the municipality level.

census data and defined as the fraction of landholdings held by the largest 10% farmers) and our proxy measure of market imperfection for each administrative area covered in the survey. Recall from the theoretical model in Section 2 that higher transaction costs τ result in a sub-optimal limited degree of transactions in land markets, which impedes the most productive farmers to work at their (larger) optimal scale. The inverse relationship observed in the figure is indicative of a negative correlation between potential land market imperfections and allocative efficiency.[6]

3.3 A Measure of Farm Productivity

We now calculate a measure of total productivity at the farm level for maize and beans. We begin by taking the residual from the production function defined in Section 2 for each particular farmer i in region j,

$$y_{ij} = s_{ij}(l_{ij})^{\alpha}.$$

We obtain the measure for total farm productivity s using the census micro-data on land and crop yields and assuming $\alpha = 0.5$, which is in the range for land income share estimated in Valentinyi and Herrendorf (2008).[7] To obtain a more accurate measure of total farm productivity we account for a set of control variables, including farmer's age and years of education, whether he/she uses enhanced seeds, type and quantity of input used, use of irrigation systems and number of crops cultivated (to capture the level of specialization). In particular, we estimate the calculated series of s_{ij} as a function of the above set of control variables plus administrative area fixed effects via ordinary-least squares. The residual of this regression is our measure of farm productivity.

For the country as a whole, the correlation between farm productivity and landholding size results in the range of 0.23-0.25, depending on the crop considered. These correlations are statistically significant at conventional levels, which suggests that the allocation of land is closely related to the farmers' productivity. In the next section, we discuss to what extent

[6]This relationship holds if we use the price per hectare that the farmer valued her own land, after controlling for land quality. The relationship also holds when using 5% and 20% concentration ratios.

[7]We perform below a sensitivity analysis using alternative values of α.

this allocation is efficient. To do this, we evaluate how the actual allocation compares with a benchmark, efficient allocation chosen by a hypothetical social planner.

4 Quantitative Analysis

In this section we quantify the magnitude of land misallocation in Guatemala at the country level. We then repeat the analysis at the regional level to evaluate geographic heterogeneity. Finally, based on the model developed in Section 2, we assess the potential channels that may explain the nature of the distortions, focusing on land market imperfections.

Our approach is built on Restuccia and Santaeulalia-Llopis (2015), who quantify factor misallocation in Malawi's agricultural sector. First, we solve a simple optimization problem of a hypothetical social planner intending to maximize aggregate output by allocating land according to the overall distribution of farmers' productivity. Second, we compare the aggregate output that results from this efficient allocation by the social planner with the actual aggregate output that would result from the land size distribution found in the data.

An efficient allocation for region j can be obtained by solving the following social planner problem,

$$Y_j^* = \max_{\{l_{ij}\}_i} \sum_{i=1}^{N} s_{ij}(l_{ij})^{\alpha},$$

subject to

$$L_j = \sum_{i=1}^{N} l_{ij}$$

where Y_j^* denotes the efficient output.[8]

The solution to the optimization problem is straightforward as the marginal product of land must be equal across farmers. The following is an expression for the efficient land allocation of an individual farmer,

$$l_{ij}^* = \frac{s_{ij}^{1/(1-\alpha)}}{\sum_i s_{ij}^{1/(1-\alpha)}} L.$$

[8]Since we focus on the land-market distortions channel, we assume that the set of control variables is exogenously given for the planner.

The theory suggests that each farmer's land size depends on her productivity relative to the whole distribution of farm productivity. Letting $S_{ij} \equiv s_{ij}^{1/(1-\alpha)} / \sum_i s_{ij}^{1/(1-\alpha)}$, it follows that,

$$Y_j^* = \sum_{i=1}^{N} s_{ij} \left(S_{ij} L\right)^{\alpha}.$$

Finally, we compare the efficient agricultural output with the agricultural output under the current land allocation defined as,

$$Y^c = \sum_{i=1}^{N} s_{ij} (l_{ij}^c)^{\alpha}$$

where l_{ij}^c denotes the actual land extension of an individual farmer observed in the census data.

Table 3 reports the results of this exercise in terms of the efficiency ratio Y^c/Y^*. The results are reported for the whole country and disaggregated by regions. A higher (lower) efficiency ratio indicates that the current land allocation across economic agents is closer to (farther from) the optimal allocation from a social planner's perspective.[9]

The efficiency ratio for Guatemala as a whole indicates the presence of a substantial degree of inefficiency arising from land misallocation. This ratio is between 0.75 and 0.8 depending on the crop, which indicates that the gap of aggregate output between the current land allocation and the theoretically efficient allocation is of around one third. In other words, if land market imperfections were removed, total output for white and yellow maize and black beans could increase by 33% from their current levels. The results by region are in line with the patterns observed in Section 3, where the efficiency ratios in the Western Highlands ('Altiplano Occidental'), i.e. the most underdeveloped region, are considerably smaller than those in Petén-Izabal, a region with much more developed commercial agriculture.

[9]For the results by region, we first calculate the farm productivity measures by department in order to account for potential heterogeneity in the response to the control variables used to clean the measure. We then calculate the efficiency ratios by department and report the average efficiency ratio across departments in a given region.

4.1 Potential channels of distortions

We now turn to assess the potential channels driving the reported inefficiency. In particular, we trace the link between the implications of land market distortions based on the theoretical framework discussed in Section 2 and the quantitative results found above.

[To be completed]

5 Conclusion

[To be completed]

References

Adamopolous, T. and Restuccia, D. (2014). The size distribution of farms and international productivity differences. *American Economic Review*, 104(6):1667–1697.

Caselli, F. Accounting for cross-country income differences, volume 1 of *Handbook of Economic Growth*, chapter 9. Elsevier.

Lagakos, D. and Waugh, M. E. (2013). Selection, agriculture and cross-country productivity differences. *American Economic Review*, 103(2):948–980.

Restuccia, D. and Santaeulalia-Llopis, R. (2015). Land misallocation and productivity. University of Toronto, Department of Economics Working Paper tecipa-533.

Restuccia, D., Tao Yang, D., and Zhu, X. (2008). Agriculture and aggregate productivity: A quantitative cross-country analysis. *Journal of Monetary Economics*, 55:234–250.

Valentinyi, A. and Herrendorf, B. (2008). Measuring factor income shares at the sectoral level. *Review of Economic Dynamics*, 11(4):820–835.

Figure 1: Equilibrium in the Simple 2-Region model

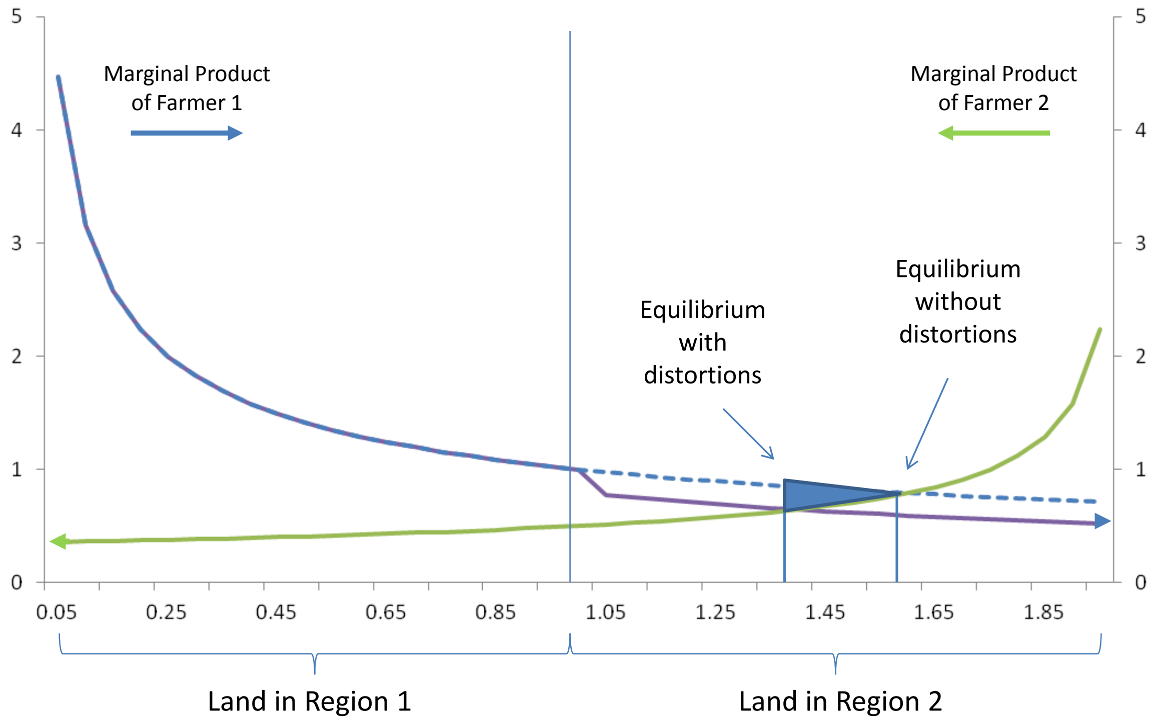

Figure 2: Share of Small and Large Farms across Departments)

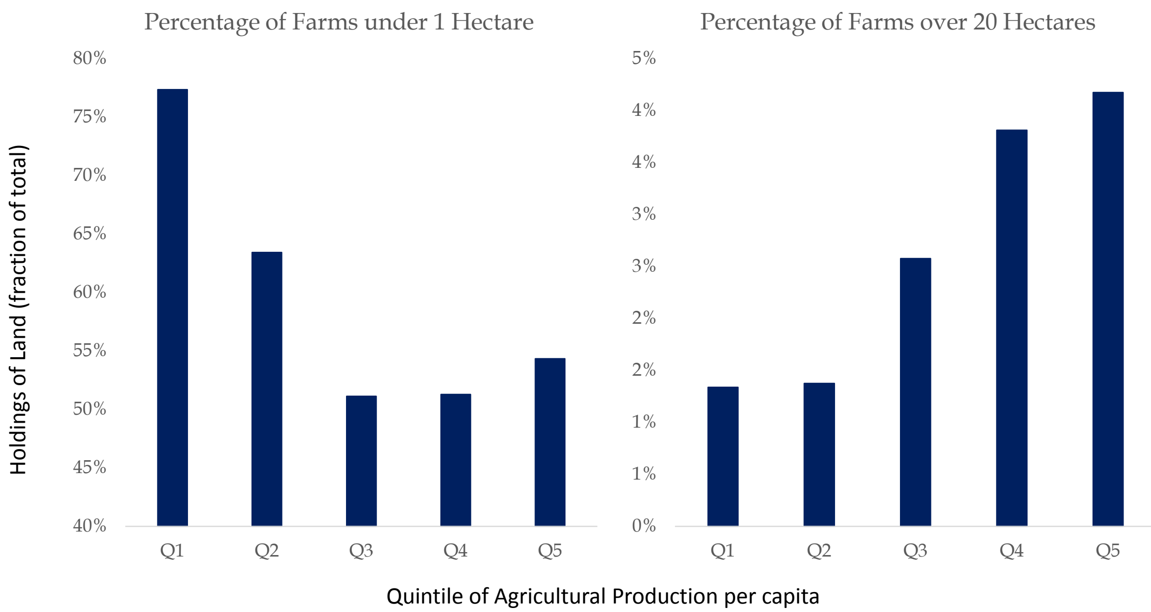

Figure 3: Landholdings Concentration Ratio and Land Price Dispersion

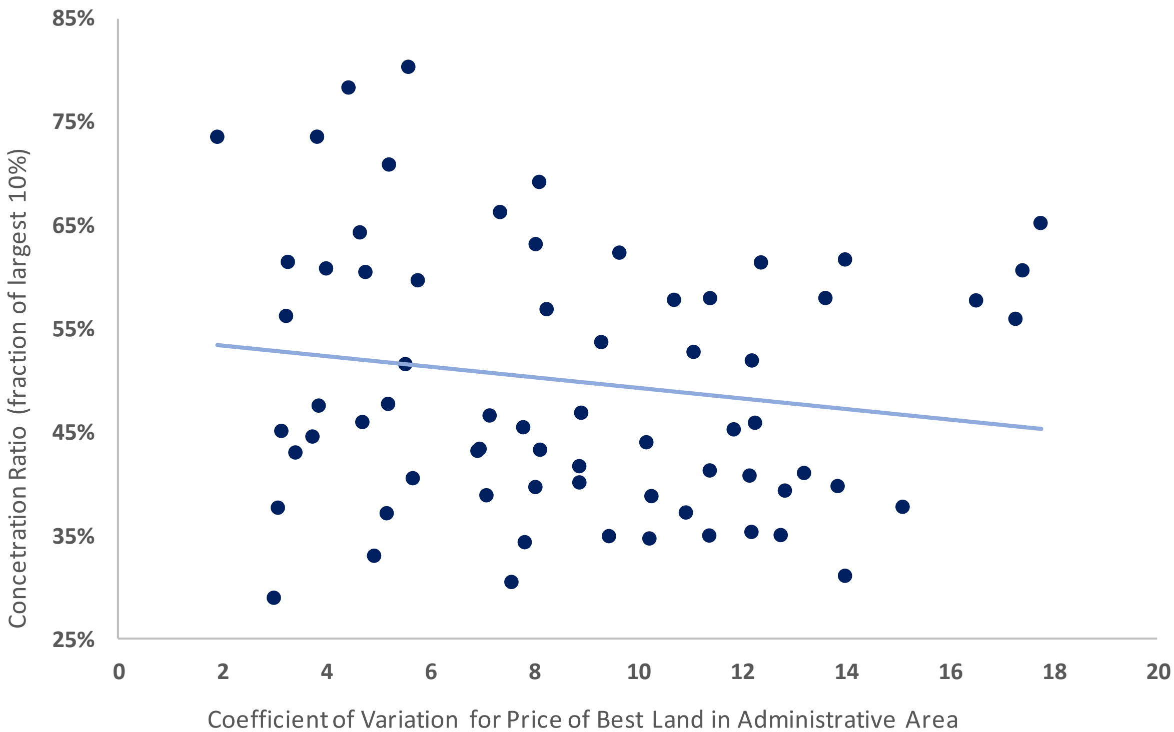

Table 1: Size Distribution of Farms (% of Farms by Size)

Landholding size	All regions	Altiplano Occidental	Corredor Seco	Petén-Izabal	Pacífico-Bocacosta	Verapaces
Less than 1 Ha	59.7%	73.5%	49.7%	15.8%	51.8%	36.0%
1 - 2 Ha	17.6%	13.9%	26.4%	15.4%	19.4%	24.3%
2 - 5 Ha	13.2%	8.3%	16.0%	24.4%	16.5%	24.1%
5 - 10 Ha	3.6%	2.1%	3.5%	8.7%	4.3%	7.6%
10 - 20 Ha	2.3%	1.3%	2.0%	6.9%	3.4%	4.5%
More than 20 Ha	3.5%	1.0%	2.5%	28.6%	4.5%	3.5%

Table 2: Dispersion of Productivity across Farms

White Maize	All regions	Altiplano Occidental	Corredor Seco	Petén-Izabal	Pacífico-Bocacosta	Verapaces
Mean	26.2	29.0	23.0	22.4	37.0	19.8
Median	23.4	27.3	20.0	20.0	35.0	16.0
St. Dev.	13.4	13.7	12.5	10.0	13.3	10.4
Coefficient of Variation	0.5	0.5	0.5	0.4	0.4	0.5
Ratio P75/P25	2.0	2.1	2.2	1.8	1.9	2.0
Number of Obs.	409,042	204,907	57,955	45,192	23,963	76,794
Yellow Maize	All regions	Altiplano Occidental	Corredor Seco	Petén-Izabal	Pacífico-Bocacosta	Verapaces
Mean	26.2	27.9	19.8	19.8	30.3	18.3
Median	24.7	27.2	18.0	16.0	30.0	16.0
St. Dev.	12.2	12.1	9.2	10.3	12.6	9.3
Coefficient of Variation	0.5	0.4	0.5	0.5	0.4	0.5
Ratio P75/P25	2.0	1.8	2.0	2.1	1.9	2.1
Number of Obs.	143,308	115,490	5,446	1,284	790	20,038
Black Beans	All regions	Altiplano Occidental	Corredor Seco	Petén-Izabal	Pacífico-Bocacosta	Verapaces
Mean	12.3	13.2	11.7	11.8	13.3	12.3
Median	11.4	12.5	10.7	10.4	12.5	11.2
St. Dev.	5.3	5.3	5.3	4.7	6.0	5.4
Coefficient of Variation	0.4	0.4	0.5	0.4	0.5	0.4
Ratio P75/P25	2.0	1.9	1.9	1.9	2.0	2.0
Number of Obs.	108,552	31,189	31,735	19,084	4,454	21,945

Table 3: Efficiency Ratio (Y^c/Y^*)

Crop	All regions	Altiplano Occidental	Corredor Seco	Petén-Izabal	Pacífico-Bocacosta	Verapaces
White Maize	76.9%	79.3%	79.2%	86.7%	76.7%	83.5%
Yellow Maize	80.7%	83.0%	75.3%	86.7%	63.7%	83.5%
Black Beans	75.3%	79.9%	77.3%	88.6%	80.0%	81.5%