Land Consolidation and Rural Labor Markets: Theory and Evidence From Colombia

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Abstract

The consolidation of land in large farms is accelerating in many developing countries. This paper studies the implications of land consolidation on rural employment and workers' welfare. I develop a general equilibrium model of local labor markets that considers both farm and nonfarm labor. Large-farm consolidation affects the demand for farm labor via labor intensity and the nonfarm labor demand through non-homothetic consumption growth. The model shows that consolidation may reduce workers' income if the pull response in the nonfarm sector is small relative to the shift in farm labor demand. I examine this question in the Colombian setting by assembling a novel dataset and leveraging quasi-experimental variation in the ability of rural counties to respond to a trade shock that changed land use. Regions with an increase in large-farm consolidation experienced a decline in the share of agricultural labor and a sizeable increase in unemployment rates. These findings shed light on the distributional impacts of consolidation across individuals and the potential implications of structural transformation within rural economies.

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1 Introduction

The consolidation of agricultural land is accelerating in developing countries. In the past two decades, more than four thousand large-scale deals have taken place.[1] Close to 60% of these deals are transactions of at least five thousand hectares, and the median size across all transactions is seven thousand hectares. Scholars suggest that this rise in demand for agricultural land is unlikely to slow given population growth trends (Liao et al., 2020; Deininger et al., 2011). Therefore, it is crucial to understand the implications of this consolidation on economic development, especially in the rural economies where this consolidation takes place.

Large-scale production has the potential to increase aggregate agricultural productivity. Despite that technology usually exhibits constant returns to scale, market imperfections render large producers more efficient as their better access to input, financial, and output markets often outweigh labor supervision costs (Ma et al., 2021; Foster and Rosenzweig, 2017; Collier and Dercon, 2014; Chavas, 2001; Putterman, 1983).[2] The productivity gains of large-scale production, however, are not necessarily evenly distributed across individuals and space. Labor is an essential endowment for a large proportion of rural households, so the extent to which rural workers benefit from land consolidation depends on local employment gains.

In this paper, I study the implications of large-farm consolidation on employment in rural economies. I focus on three main questions of interest: Does the consolidation of land affect the local allocation of labor across sectors? Do rural workers benefit from this consolidation? And what are the potential economic mechanisms driving the effects?

I study these questions in the context of rural Colombia, where land concentration has been historically high, and 40% to 50% of agricultural land is consolidated in large farms. Two main features make this setting particularly relevant to study these questions. First, a majority of rural households are landless (58%) and derive most of their income from labor markets. Second, one of the provisions of the 2016 Peace Agreement is to redistribute at least 2.6 million hectares to landless peasants and farmers with insufficient acreage (Arteaga et al., 2017). This analysis is also relevant for other developing contexts where large-scale land deals are taking place since many of the stylized patterns that I document for Colombia are likely general to rural economies in low and middle-income

[1] These numbers refer to completed transactions of at least five hundred hectares for agricultural activities. For more details on this data, see the Land Matrix Project.

[2] Of course, some crops can still be produced competitively at different scales depending on local factor endowments and labor costs (Deininger et al., 2011). Specialty and certified coffee, for instance, are often more profitable when produced at a small scale.

countries.

This paper develops a two-sector general equilibrium model of local economies to analyze the implications of land consolidation on employment and the equilibrium wage. This model combines two microeconomic insights common to agricultural production models – differences in factor intensity across the farm size distribution and efficiency gains from scale – with a third feature that links income concentration and nonfarm labor demand – the non-homothetic demand growth for local goods. A key feature of the model is that land consolidation simultaneously affects the demand for labor in both economic sectors.

Using this framework, I show that consolidation leads to a push response in the demand for labor out of the farm sector and a likely pull response in nonfarm labor demand. On net, if the pull response is small relative to the push response in the farm sector, consolidation may lead to labor reallocation away from the agricultural sector along with a reduction in wages. These theoretical results imply the opposite relationship than we usually associate with the process of structural transformation and highlight the importance of local multiplier effects to generate employment gains after consolidation.

Next, I empirically examine the impact of a specific shift in land concentration that occurred during the 1990s. This shift was largely driven by a change in the terms of trade that transformed land use in the country. The area in pastures and land-intensive crops increased by more than two million hectares, while coffee and other labor-intensive crops lost important participation in agricultural land (Balcázar, 2003). Overall, the gini of landholdings displayed a slight increase between 1993 and 2005 and large-farm consolidation changed in almost all the municipalities.

I study this shift in land concentration using a novel panel dataset of rural municipalities with measures on employment and land consolidation. This dataset links information from different sources, including the population census, the national household surveys, and the rural cadastre. I examine impacts on the reallocation of labor across sectors and workers' income using measures of wages and unemployment rates, and define large-farm consolidation as the share of area in large farms in each municipality.

To estimate treatment effects, I leverage quasi-experimental variation in the ability of local economies to respond to land-use changes driven by trade liberalization. Specifically, I construct an instrument for the change in large-farm consolidation based on topographic features of the terrain that influence the financial viability to produce at large scale. Consolidation is negatively correlated with the terrain's degree of inclination since it is cheaper to produce at large-scale in flatter grounds due to infrastructure's construction costs and cattle carrying capacity.

I account for two main factors that might be correlated with a town's topography and represent a threat to the exclusion restriction of the instrument. First, the differential effects in agricultural production and labor force participation driven by the upsurge of conflict in rural areas (Fernández et al., 2014; Arias et al., 2018). Second, labor market trends associated with crop suitability, including the potential income effects after the shift in the terms of trade. For instance, changes in tariffs and relative prices were more likely to benefit economies that had an *absolute* advantage to produce exportable crops such as flowers and oil palm. My analysis compares adjacent towns with similar agricultural suitability but distinct feasibility to produce at scale, so the variation I exploit arises from the ability to consolidate rather than the *absolute* advantage to produce a particular crop.

I find that the rural economies with an increase in large-farm consolidation experienced a reallocation of labor out of the agriculture sector. Specifically, a one standard deviation increase in consolidation resulted in a ten percentage point decline in the share of farmworkers. In addition, consolidation led to a fourteen percentage point increase in the unemployment rate with no significant change in wages, suggesting that this reallocation of labor was accompanied by a net negative impact on workers' income. My estimates imply that one standard deviation increase in land consolidation - corresponding to a twelve percentage point rise in the share of area in large farms– explains 70% of the observed decline in farm employment for the *average* Colombian municipality between 1993 and 2005.

I provide evidence that these findings are not driven by several factors that may confound the relationship between employment and the instrument. First, parallel pre-trends support the exclusion restriction that topography does not lead to differential trends in labor markets across similar towns. Second, results are unchanged when controlling for the upsurge of conflict and forced displacement during this period. These findings are also robust to the use of different inference procedures, including alternative types of intra-cluster correlation and size corrections for weak instruments.

Taken together, my findings indicate that consolidation led to a decrease in the demand for farmworkers and an absolute reduction in the demand for rural labor. These results are consistent with the model's predictions when the pull response in the nonfarm sector is small relative to the push response in the farms. While I cannot directly test for mechanisms, descriptive results corroborate the importance of non-homothetic consumption growth, as the absolute decrease in labor demand appears to be smaller in economies where local multiplier effects are expected to be large.

My results on unemployment suggest that labor mobility across space was not large enough to offset the decrease in labor demand after consolidation.[3] These findings are

[3] This is not to say that the extent of rural-out migration was small during this period. On the contrary,

consistent with the low levels of integration across rural labor markets during the 1990s (Nupia, 1997) and the prevalence of different barriers that limit migration in developing contexts (Morten and Oliveira, 2018; Dix-Carneiro and Kovak, 2017; Bryan et al., 2014). Since my period of analysis spans twelve years, an important implication of these results is that land consolidation has lasting effects on local labor markets. This is in line with previous empirical work that examine the capacity for labor markets to respond to economy-wide shocks and document persistent effects in the short and medium run (Dix-Carneiro and Kovak, 2019; Dix-Carneiro, 2014; Autor et al., 2014; Artuç et al., 2010). For instance, Dix-Carneiro and Kovak (2019) find that the effect of Brazil's trade liberalization on local unemployment and informality persisted over ten years.

The theoretical framework developed in this paper has implications for the design of future land policies. In particular, the model suggests that the effect on local labor markets depends on the initial level of concentration and the type of consolidation since the strength of the pull response in the nonfarm sector varies across the farm size distribution. In work in progress, I calibrate the model to Colombian farm-level data to examine two counterfactual scenarios that might take place with the future redistribution policy.[4] One redistributes land from large to middle-sized farms while the other increases the proportion of area in small farms. For each counterfactual, I will quantify the effects on wages and the labor reallocation across sectors, assess how much of these effects are driven by non-homothetic local consumption growth, and evaluate impacts in the short and long term using different levels of labor mobility across space.

This paper contributes to the long-standing literature that examines the relationship between land allocation and economic development. This literature includes theoretical work that micro-founds the connections between scale and aggregate productivity (Ma et al., 2021; Foster and Rosenzweig, 2017; Henderson and Isaac, 2017; Eswaran and Kotwal, 1986; Carter and Kalfayan, 1989), and macroeconomic models that quantify the contribution of misallocation to productivity gaps (Santaeulàlia-Llopis, 2021; Adamopoulos and Restuccia, 2020; Adamopoulos et al., 2019; Chen, 2017; Adamopoulos and Restuccia, 2014). My work complements these studies by examining implications for local labor markets and adds to this literature by introducing a framework that considers the links between the scale of production and labor demand in both the farm and nonfarm sectors. This

due to the upsurge of conflict, a large proportion of rural households were forced out of rural communities. In my analysis, however, forced displacement is a potential threat to internal validity. Thus, my empirical strategy compares municipalities with a similar incidence of this type of labor mobility. Future access to net migration flows will allow me to assess how much of the observed changes are driven by economic migration.

[4] See Appendix B for more details on this ongoing analysis.

framework combines insights from the relationship between farm size and productivity with two insights from the literature on the rural nonfarm economy: the importance of local consumption on employment in the nonfarm sector (Foster, 2011; Haggblade et al., 2009, 2007; Foster and Rosenzweig, 2008; Lanjouw and Lanjouw, 2001), and the connection between income concentration and labor demand (Mellor, 2017; Ranis and Stewart, 1993). By embedding these insights into a general equilibrium framework, I show that land consolidation has different impacts across individuals as it could negatively affect rural workers despite the productivity gains.

This paper also contributes to the growing empirical work that examines the effects of large-scale transactions on the welfare of rural populations (Liao et al., 2020; Ali et al., 2019; Deininger and Xia, 2016). With a few exceptions, this body of work consists of descriptive studies that rely on cross-sectional data and unconfoundedness to estimate spillover effects on smallholders (Bottazzi et al., 2018; Herrmann, 2017; Jiao et al., 2015). My empirical strategy allows me to relax the assumption of unconfoundedness by using a 2sls approach along with panel data. I contribute to this literature by providing novel empirical evidence on the economy-wide impacts of large-scale consolidation on aggregate employment and wages.

A second line of work related to this paper is the literature on structural transformation (Herrendorf et al., 2014). My findings show that land consolidation is another driver of the reallocation of labor across sectors. My empirical work relates to the research on the impacts of trade on structural transformation (Farrokhi and Pellegrina, 2020; Fajgelbaum and Redding, 2018; McArthur and McCord, 2017). In particular, Laskievic (2021) finds that commodity price booms affect labor reallocation through greater land inequality and changes in input use. While these papers study the direct effect of trade leveraging the differential exposure of municipalities to shocks, I examine the direct impact of land consolidation by exploiting the isolated effect of trade on land concentration across towns with similar exposure to shocks. Methodologically, my empirical approach is similar to previous work that exploits quasi-experimental variation to examine the determinants of structural change at a local level rather than across regions (Bustos et al., 2020; Uribe Castro, 2020; Bustos et al., 2016; Foster and Rosenzweig, 2008).

Finally, my findings also indicate that the reallocation of labor out of the farm sector can occur along with a decrease in workers' income. This implies the opposite relationship than we usually observe with the process of structural transformation. These results are related to recent studies that examine the spatial implications of structural transformation (Bustos et al., 2020; Eckert and Peters, 2018; Nagy, 2016; Desmet and Rossi-Hansberg, 2014; Michaels et al., 2012; Caselli and Coleman II, 2001). In particular, Eckert and Peters (2018) also quantify a reduction in rural income per capita after the transformation of the US economy during the 20th century. In line with their work, my empirical results shed light on the prevalence of barriers to the mobility of workers across space.

The rest of this paper is organized as follows. In the next section, I establish empirical patterns that relate large-farm consolidation and employment in each sector. Section 3 develops the model and discuss its main analytical insights. In Section 4, I describe the empirical setting and examine the impact of large-farm consolidation during the 1990s in Colombia. Section 5 concludes.[5]

2 Empirical Patterns Relating Farm Size and Labor Demand

In this section, I establish four descriptive patterns that relate farm size to the demand for workers in agricultural and nonagricultural sectors. These patterns motivate the mechanisms and the structure of the model that I propose in Section 3. These patterns are obtained using data from the *2014 National Agricultural Census*, the *2016 National Household Survey*, and the cost study of agricultural crops conducted by Perfetti et al. (2012).

Pattern 1. *Input intensity in agriculture varies with farm size*

One empirical regularity that has been documented in low and middle-income countries is that labor intensity per hectare decreases with farm size (Carter, 1984; Sen, 1981; Deininger et al., 2016). Figure 1 shows that this relationship holds for the main crops in Colombia, including coffee, oil palm, and rice.[6] By contrast, Figure 2 shows that large producers are more likely to use machinery and small equipment tools for agricultural production. In particular, farmers with 500+ hectares are 5.5 times more likely to own equipment than farmers with less than 3 hectares of land. This variation in input intensity across the size distribution implies that large producers are more likely to substitute labor for farm equipment in production. Thus, a farmer's demand for workers per hectare will depend her the farm size.

Pattern 2. *Nonfarm employment depends largely on local consumption*

By 2017, 40% of rural workers had a primary job in the nonagricultural sector. This sector is composed of all activities that do not make an intensive use of land to raise livestock or produce crops and raw materials. In Figure 3, I show that two-thirds of the workers

[5]For details on the ongoing calibration exercise, see Appendix B.

[6]This relation remains practically unchanged when using the total area cultivated as opposed to the total farm size. It also holds when using the total number of permanent workers as a measure of employment instead of the total man days.

in this sector work in industries that produce services or goods that are nontradable. Notably, 19% work in the provision of personal and social services, 8% work on construction, and 22.5% work in retail.[7] These observations imply that local consumption is a crucial driver of employment in the nonfarm sector. The following patterns suggest two ways through which this consumption could be affected by the concentration of land in large farms.

Pattern 3. *Large producers benefit from economies of scale in equipment markets*

Figure 4 documents that large producers usually spend less money per hectare on farm equipment. This regularity holds for different crops and across multiple agricultural regions in the country. Given the patterns in equipment use documented above, this difference in costs implies economies of scale in equipment markets. In particular, large producers tend to face a lower rental price of farm equipment than their smaller counterparts.[8] This observation is further supported by qualitative interviews in the field that point to the existence of nonlinear pricing in the cost of machinery services. For instance, the rental price of a tractor service per hectare is U$40 for farms with less than 100 hectares and U$33 (or less) for larger farms.[9] These advantages in equipment markets render production at scale more profitable. Thus, to the extent that these profits are used for local consumption, large producers can generate higher multipliers effects in the nonfarm economy.

Pattern 4. *Large producers are less likely to spend a high share of their income in the local economy*

Multiple scholars have documented the prevalence of absent landholders in Colombia (Adams, 1966; Edel, 1971; Piniero, 2016). These landholders are usually large producers that live in the city most of the year. In recent work, Robineau et al. (2010) document that 40% of the farmland in two municipalities close to the capital belongs to absentee owners who hire a manager to take care of the production. More generally, the *2014 Agrarian Census* reports that a large share of producers (73.3%) do not live permanently on their farms. One implication of the absenteeism of large producers is that the demand for nontradable goods in the rural economy will depend on how concentrated the agricultural profits are. This is also the case when all producers live in the rural economies, as it is reasonable to

[7] I consider retail goods as nontradable, even though some of these are imported from larger cities. The motivation behind this choice is that these goods are almost exclusively consumed within the local economies.

[8] Formally, let $\frac{p_j k_j}{h_j}$ be the the total cost of equipment per hectare for a farm with size j, where $j =$ small, large. If $\frac{k_s}{h_s} < \frac{k_l}{h_l}$, then $\frac{p_s k_s}{h_s} > \frac{p_s k_s}{h_s}$ implies that $\frac{p_s}{p_l} > \frac{k_l h_s}{k_s h_l} > 1$.

[9] These nonlinearities in input pricing are not unique to equipment markets. Bulk pricing is a common practice in the markets for fertilizers and pesticides.

think that wealthier producers are more likely to replace local goods with higher-quality counterparts produced and sold in the cities (De Janvry and Sadoulet, 1993).

3 Two-Sector Model of Local Labor Markets

In this section, I develop a static model of a rural economy with two sectors. This model features a small-open economy where farmers are heterogeneous in their landholdings, input demands vary with plot size, and local consumption is crucial for rural employment. This model aims to rationalize the empirical patterns described in Section 2 and provide a framework to quantify the implications of the pending land reform on rural employment in Colombia.

In the first subsection, I present the economy's endowments, the market environment, and the technologies. Then, I define the competitive equilibrium and explain the intuition behind the comparative statics. The last subsection examines the type of land transactions that would occur with sale markets in the long run, as these markets played a crucial role in the change in land concentration that I study in Section 4.

3.1 Environment

Consider a small open economy that produces an agricultural crop q_a and a nonagricultural good q_n. The prices of these two goods are p_a and p_n, respectively, and the non-agricultural good is nontradable. In this economy, individuals consume these two locally produced goods, in addition to a third good that is produced and sold in the city q_c. This city good is a higher-quality substitute for the non-agricultural good that is produced locally.

This local economy is endowed with fixed amounts of labor L, farmland H, and capital equipment K. All individuals are endowed with one unit of labor that is supplied inelastically but have different endowments of land. There are θL agents that have landholdings, and each one of them has a different endowment of hectares given by the distribution $f(h)$. Once landholdings are realized, individuals make their choices in two stages. First, they choose inputs to maximize profits, and then they finance consumption with their disposable income.

In this model, agents are competitive in output markets, and labor is perfectly mobile across sectors. This latter assumption implies a unique equilibrium wage w, which precludes selection as a potential channel for the allocation of employment across sectors. Consistent with the patterns documented in Section 2, there are pecuniary economies in the agricultural capital market. Namely, the effective rental price that farmers pay per unit of capital R_i varies across agents and decreases with holding size, i.e, $R_i'(h_i) < 0$. The land market in this model also departs from its competitive benchmark. Notably, land cannot be rented in or rented out. This assumption is consistent with the finding that rental markets in Colombia are thin due to high informality and credit rationing (Gáfaro et al., 2014). Thus, this static model is intended to explain how exogenous shifts in the farm size distribution affect rural employment rather than how this new distribution emerges.[10]

3.1.1 Technologies:

Agriculture: the agricultural good is produced using land h, labor ℓ_a, and capital k_a. The technology features constant returns to scale and is given by

$$q_a = h^{\gamma}[\eta \ell_a^{\rho} + (1-\eta)k_a^{\rho}]^{\frac{1-\gamma}{\rho}}$$

where γ is the output elasticity of land and $\eta \in (0,1)$ captures the relative importance of labor to capital in production. The parameter $\rho < 1$ determines the elasticity of substitution between labor and capital, i.e. $\sigma = \frac{1}{1-\rho}$. As $\rho \to 1$, labor and capital become highly substitutable.

Nonagriculture: the nonagricultural good is produced by a stand-in firm. The technology uses labor and capital and features constant returns to scale:

$$Q_n = L_n^{\alpha} K_n^{1-\alpha}$$

The nonfarm good is nontradable and thereby production depends on local demand. This characterization precludes the production of value-added products to focus attention on the role of local consumption as a driver of employment in this sector (see Section 2).[11] In contrast to agricultural production, there are no pecuniary economies in the production of the nonfarm good. Thus, the effective price of capital for the stand-in firm equals the equilibrium rate r and $\pi_n^* = 0$.

[10] See Section 3.4 for a discussion on the role of sale markets in the consolidation of land in the long run. For a two-sector static model that endogenizes the farm size distribution, see Adamopoulos and Restuccia (2014) and Chen (2017).

[11] According to the National Household Survey, manufacturing of food, beverages, tobacco, and leather products only contributed with 8% of rural nonfarm employment in 2017. This represents a two percentage point increase since 2006.

3.1.2 Preferences:

I consider an economy where agents consume three types of goods. Two of them are the agricultural $\{c_a\}$ and nonagricultural $\{c_n\}$ goods produced in the rural economy. The third one is a good that is produced and sold in the city $\{c_c\}$, which is a higher-quality substitute for the locally produced (and traded) nonfarm good. Agents choose consumption to maximize

$$\begin{aligned} \max_{c_a, c_n, c_c} \quad & u(c_a, c_n, c_c) = \omega_a log(c_a - \bar{c_a}) + \omega_n log(c_n) + \omega_c log(c_c + \bar{c_c}) \\ \text{s.t.} \quad & p_a c_a + p_n c_n + p_c c_c \leq Y \end{aligned} \tag{1}$$

where ω_j is the relative weight for good j, $\bar{c_a} > 0$ is a subsistence constraint of food consumption, and $\bar{c_c} > 0$.[12] The motivation behind these non-homothetic preferences is to account for the observation that changes in income lead to changes in expenditure shares (see the fourth pattern documented in Section 2). If $\bar{c_a} > 0$, the income elasticity of the agricultural good is less than one. If $\bar{c_c} > 0$, the income elasticity of the city good is greater than one.[13]

3.1.3 The Agent's Problem:

The problem for each agent can be solved in a recursive way. First, she maximizes income. Then, she chooses consumption demands subject to that income. The disposable income of a landless agent is given by the value of their labor endowment $Y = w$. The disposable income of a farmer is given by the sum of the value of their labor and the agricultural profits, $Y = w + \pi_a^*$.

Given the market environment, agricultural profits are given by:

$$\max_{\ell_a, k_a} \quad \pi_a = p_a q_a - w\ell_a - R_i(h)k_a \tag{2}$$

To gain insight, I posit that the effective rental price for each farmer i is

$$R_i(h) = r\Big(1 + \frac{1}{h_i^\nu}\Big)$$

where r is the benchmark price that is determined in equilibrium and $0 < \nu < 1$.[14]

[12]Intuitively, $\bar{c_c} > 0$ can be interpreted as gifts from relatives who live in the city or public policies that grant access to nonfarm goods from the capital.

[13]Note that these preferences are defined if $Y \geq p_a \bar{c_a}$

[14]This functional form implies that $R_i'(h_i) < 0$ and $R_i''(h_i) > 0$. Further, given the parametrization in Section B.1, $R_i \in (r, 2r)$.

3.2 Equilibrium

I focus on the competitive equilibrium of the model. Given the market environment, three prices are endogenously determined. These prices are the equilibrium wage w, the benchmark rental price of capital r, and the price of the nontradable good p_n. The price of the agricultural crop p_a is set in the international market, and the price of the city good p_c is set in the city.

Market of nonfarm good: the problem for the stand-in firm that produces the non-farm good implies that aggregate production is perfectly elastic. This indicates that total production is pinned down by the aggregate consumption of the good,

$$Q_n = C_n = (1-\theta)Lc_n^0(w) + \theta L\left[\int^{h^{-1}(\widetilde{Y})} c_n^1(h)dF(h) + \int_{h^{-1}(\widetilde{Y})} c_n^2(h)dF(h)\right] \tag{3}$$

where $c_n^0(w)$ is the consumption function of landless agents, and $c_n^2(h)$ $(c_n^1(h))$ is the consumption for agents who do (do not) purchase the city good.[15] Since $\pi_n^* = 0$, p_n^* equals the marginal cost $MC(w,r)$ in equilibrium.

Labor market: the clearing condition that defines the equilibrium wage in this economy is given by the equality of total labor supply and total labor demand,

$$\bar{L} = L_n + L_a = L_n + \theta L \int \ell_a(h)dF(h) \tag{4}$$

The aggregate labor demand equals the sum of the demand for workers in the non-farm sector L_n and the total workers required by the farmers L_a. Since the supply of the non-farm good is perfectly elastic, L_n is pinned down by local consumption C_n.

Capital market: the clearing condition in the capital market is given by,

$$K = K_n + K_a = K_n + \theta L \int k_a(h)dF(h) \tag{5}$$

where K is the total supply of capital equipment in the economy, K_n is the amount of capital used in the nonfarm sector, and K_a is the aggregate demand for capital in the farms.

[15] $\widetilde{Y}$ is the income threshold at which agents start consuming the city good.

Definition 1. *The equilibrium in this economy is given by input demands $\{L_a, L_n, K_a, K_n\}$, consumption demands $\{C_a, C_n, C_c\}$, and prices $\{w, r, p_a, p_n, p_c\}$; such that:*

1. Input demands in agriculture satisfy the agent's optimization in Equation 2.

2. Consumption demands are consistent with the agent's optimization in Equation 1.

3. Total production of the nonfarm good is given by Equation 3, and $p_n^* = MC(w, r)$.

4. Labor market clears following the equality in Equation 4.

5. Capital market clears following the equality in Equation 5.

6. Total farmland equals the sum of endowments across landed agents: $H = \theta L \int h_i dF(h)$.

The exogenous price p_a^* is set internationally and p_c^* is set in city.

3.3 Model Characterization

3.3.1 Partial Equilibrium Relationships

In what follows, I derive partial equilibrium relationships that are consistent with the empirical patterns presented in Section 2.

Proposition 1. *If $\frac{1}{\sigma} < \gamma$, labor (capital) per hectare decreases (increases) with holding size.*

This proposition indicates that if the elasticity of substitution is high, large producers will substitute labor for capital and become less(more) labor(capital) intensive than their smaller counterparts. This substitution is driven by the nonlinearities in the pricing of capital. If $R_i = r$ for all producers, input intensity would not vary across farm size.

Proposition 2. *Profits per hectare increase with holding size.*

Proposition 3. *There exists an income threshold $\widetilde{Y}$ at which agents start purchasing the city good:*

$$\widetilde{Y} = p_a \bar{c}_a + \frac{p_c \bar{c}_c (1 - \omega_c)}{\omega_c}$$

Further, if $p_a \bar{c}_a < p_c \bar{c}_c$, the expenditure share of the local nonfarm good is hump-shaped.

Given $\bar{c}_c > 0$ and the subsistence constraint $\bar{c}_a > 0$, individuals with low income set $c_c = \bar{c}_c$ and spend their money on food and the locally traded nonfarm good. As income increases, the subsistence constraint ceases to bind, and individuals start substituting expenditure in food with expenditure on the nonfarm good.

At higher levels of income, $Y > \widetilde{Y}$, individuals can afford to purchase the good that is produced and sold in the city ($c_c > \bar{c}_c$). Moreover, given their non-homothetic preferences, they also start spending a higher share of their income on it. If $p_a \bar{c}_a < p_c \bar{c}_c$, this share increases at a higher rate than the rate at which the expenditure share in food decreases. In this case, wealthy individuals finance their consumption of the city good by reducing the expenditure share in both food and the nonfarm good.

3.3.2 Mechanisms

In this subsection, I describe the main mechanisms behind the effect of an exogenous increase in large-scale concentration on sectoral employment and the equilibrium wage. To illustrate the intuition, consider Panel A of Figure 5, which features the rural labor market. In this figure, the x-axis represents the total supply of workers in the economy, and the red line represents the demand for farm and non-farm labor. The blue line depicts the demand for non-farm labor, which has its origin in the bottom right corner of the figure.

Effect on the equilibrium wage: an increase in large-scale consolidation will have two main effects on the equilibrium wage. First, an increase in the average plot size in the economy will result in a decrease of labor intensity, and thereby a reduction in farm labor demand (i.e. labor intensity effect). Second, consolidation will affect the demand for nonfarm labor since the expenditure in local consumption, $\mathcal{C}_n$, varies with the changes in agricultural profits. In contrast to the labor intensity effect, this shift in the demand for nonfarm labor is ambiguous as it depends on two offsetting effects. On one hand, a larger average plot size increases agricultural profits and thereby the income to spend in the local economy (i.e. profit effect). On the other, the concentration of profits will decrease the income share allocated to local consumption, as wealthier farmers are more likely to replace local consumption with goods that are only sold in the city (i.e. budget share effect). Given these offsetting effects, the shift in the demand for nonfarm labor as a consequence of large-scale consolidation will depend on whether the positive profit effect is larger than the negative budget share effect. If the positive effect is larger, the demand for nonfarm labor will increase (i.e. positive pull response). Conversely, if the budget share effect is larger, there will be a decrease in the nonfarm labor demand (i.e. negative pull response).

To illustrate how these three effects impact the equilibrium wage, refer to Figure 5 . If there is a negative pull response in the nonfarm sector, the demand for nonfarm labor will decrease and there will be an *unambiguous* reduction in the equilibrium wage (Panel B). In contrast, if there is a positive pull response, the net effect on the wage will be *ambiguous* and will depend on whether the increase in the demand for nonfarm labor is large enough to offset the labor intensity effect (Panel C).

Effect on the share of agricultural workers: similar to the analysis on the comparative statics for the wage, the effect of an increase in concentration on the share of agricultural workers will depend on the sign and magnitude of the shift in the demand for nonfarm labor. A positive pull response will result in a decrease in the share of farm workers, as the gap in sectoral wages will promote the reallocation of labor from the farm to the nonfarm sector until a new equilibrium emerges. Meanwhile, a negative pull response will result on an ambiguous overall effect since the type of reallocation will depend on the relative strength of the inward shifts in both curves.

Two important insights emerge from this analysis. First, land consolidation affects the demand for both farm and non-farm labor. Second, the sign of the overall effect on the equilibrium wage is ambiguous. This overall effect depends on the interaction of three main competing effects. The labor intensity effect, the profit effect, and the budget share effect.

3.4 Does Land Get Consolidated Via Sales Markets In The Long Run?

In the model I put forward above, land cannot be rented, and thereby, the size distribution only changes due to exogenous policies. In the long run, however, the size distribution can change through the operation of the sales market, as it was the case studied in Section 4, where land concentration changed due to a trade shock that changed the relative profitability of cash crops. To analyze the role of sales markets in the model proposed above, in this section, I follow Carter and Salgado (1998) and Carter and Zegarra (1994) and compare the competitiveness of landholders in the sales market using a land valuation exercise. The question at hand is: what type of transactions would take place if competitive sales markets are considered?

Given the model in Section 3.1, an agent's willingness to rent land is given by her shadow rental price:

$$\mu_i = \gamma h_i^{(\gamma-1)}[\eta(\ell_i^*)^\rho + (1-\eta)(k_i^*)^\rho]^{\frac{(1-\gamma)}{\rho}}$$

where h_i is the size endowment and ℓ_i^* and k_i^* are the optimal demands for labor and capital, respectively.[16] Thus, we can obtain a measure of land valuation for each agent i as

[16] Note that if rental markets were thick and considered in the modeled, an agent's willingness to pay to rent land would be equal to the market rental price.

the capitalized stream of the income increments given by this shadow rental price:

$$\Delta_i = \sum_{t=1}^{T} \frac{\mu_{it}}{[1+r]^t}$$

where r is the interest rate and T is the time horizon over which the household expect to receive benefits from that land. This measure represents the net present production value of land for each agent. Notably, if a household wants to buy (sell) one unit of land, Δ_i is the maximum (minimum) price that agent i is willing to pay (accept) for that unit without losing money. The higher this value, the more competitive an agent is in the sales market as land will flow to those agents with a higher willingness to pay.

Proposition 4. *If $\mu_{it} = \mu_i$ and $\gamma < 1$, the net present production value of land increases with plot size*

$$sign\Big(\frac{\partial \Delta_i}{\partial h}\Big) = sign\Big(\frac{\partial \mu_i}{\partial h}\Big) > 0$$

The proposition above implies that large producers place a higher value on land. In particular, given advantages in capital markets, they are more productive and thereby more willing to pay a higher price than small producers for one unit of land. This difference in the valuation of land makes large holders more competitive in sales markets. Thus, since the land will flow from smaller to larger producers, these results suggest that the model would predict a consolidation in large farms if sales markets are considered.

This net present value approach to land valuation is useful and informative about the core income factors that shape the willingness to pay for land. Yet, in comparison to a dynamic general equilibrium model, it abstracts away from risk and intertemporal consumption choices that may also affect the willingness to pay for land (Carter and Kalfayan, 1989; Carter and Salgado, 1998; Carter and Zegarra, 1994). While these two factors may have opposing effects on the competitiveness of smallholders, previous research shows that their consideration may reduce their land valuation even further (Carter and Zimmerman, 2000). Thus, the results obtained with a dynamic model will probably enforce the long-run tendency to consolidate land in large farms.

4 The Impact of Large-Farm Consolidation on Rural Employment

This section examines the impact of a specific shift in land concentration during the 1990s in Colombia. This shift was largely driven by the market integration with the World's economy, which increased the area in land-intensive crops. I first introduce the data and context. Then, I describe the empirical strategy. Finally, I discuss the results and their implications in light of the model in Section 3.

4.1 Data Sources and Study Population

I gather data from multiple sources and put together a dataset of municipalities for the years 1993 and 2005. Municipalities are the smallest administrative units in the country and are a good approximation to local labor markets since most of their inhabitants work within their geographic boundaries.[17] I focus on rural economies and exclude large cities and their main agglomerations using the definition proposed by the *Rural Mission* in 2014.[18] To account for the segregation and creation of new municipalities across time, I use a consistent unit of observation based on the official boundaries of the municipalities in the year 1993. In my final sample, only 4% of the units of observation are composed of two or more adjacent municipalities.

Unemployment and sectoral employment: I use information from the National Population Census of 1993 and 2005 to construct these measures. These two rounds of the census collect information on labor participation and the industry of employment, in addition to the usual demographic and socio-economic characteristics collected in other rounds.[19] For each municipality, I compute the unemployment rate as the ratio of the number of unemployed individuals to the total population that is economically active. Similarly, I construct the share of agricultural workers using information on the economic sector of the main job in the last 15 days. I define agricultural jobs as those activities that make an intensive use of land to produce crops and raw materials, raise livestock and poultry, or farm fish. Any other activities, including the processing of food and beverages, are classified as non-agricultural jobs.[20]

Wages: Since the population census does not collect data on wages, I use individual-level data from the National Household Surveys (ENH) of 1998 and 2009. These repeated cross-sections are representative at the national and department level and include a large set of rural municipalities that are selected at random each round. The employment mod-

[17] According to the population census of 2005, 95% the workers who lived in rural municipalities worked in the same municipality where they lived.

[18] This definition classifies municipalities in four categories based on population density and the number of inhabitants living in the town's seat. See Ocampo (2014) for more details.

[19] These two rounds of the Population Census have been shown to be comparable despite their differences in implementation (Le Roux, 2013; Mallarino, 2007; Jaramillo and Ibáñez, 2005). Access to this data was obtained per confidential agreement with the National Department of Statistics.

[20] Two main reasons indicate that the timing of data collection does not primarily drive the differences in agricultural employment across locations. First, in most regions, the share of agricultural workers does not vary much throughout the year (see Figure A1 in the appendix). Second, according to experts at the National Department of Statistics, the roll-out of the censuses was not correlated with any particular season.

ule of this survey collects data for a random sample of workers on features such as occupation, hours worked, and income. I compute the hourly wage for each worker as the ratio of her monthly wage to the number of hours worked during the last month, and convert nominal to real values using the price index of 1993. For all outcomes, I focus on individuals between 15 and 65 years old.

Land consolidation: I use data from the national cadastre system for the years 1993 and 2005 to construct measures of land consolidation.[21] This system is a census of all the properties in the country with detailed information on the location of the plot, the type of holder, and the plot's size.[22] For each municipality and year, I have information on the number of properties and their total area across thirteen size ranges.[23] To focus on privately held land, I exclude the records of indigenous reserves and properties that belong to the State. Two main features make this data advantageous to construct measures of concentration and consolidation. First, the system records information based on possession instead of ownership. Therefore, the records of private land include farmers with informal titles or settled in vacant public lots. Second, the measures of plot size are less likely to be afflicted by self-reporting bias – common in survey data– as the data gathered upon the *cadastre formation* is collected and updated by personnel in the field (IGAC, 1988).[24]

I define large-farm consolidation as the share of area in large farms. To determine what a large plot is for each town, I use as reference the average family farm unit, a policy instrument representing the minimum plot size needed to generate an income surplus given the agro-ecological conditions of the plot's location.[25] Following Machado and Suarez (1999), I use a threshold of ten units to characterize large plots. Therefore, large-farm consolidation for each municipality i is given by: $\omega_i^{large} = \omega_i^{a} \quad if \quad \kappa_i \in [a, b)$, where κ_i refers to ten

[21]The data from 2005 was purchased from the National Institute of Geographic Information (IGAC), and the data from 1993 was generously provided by Fabio Sánchez at the University of the Andes in Colombia.

[22]The national cadastre is managed by five different agencies: the National Institute of Geographic Information (IGAC), the department of Antioquia, and the capital cities of Bogota, Medellin, and Cali (IGAC, 2012). In this analysis, I use the information from Antioquia and IGAC, which constitutes the whole universe of rural municipalities with cadastral data.

[23]These size ranges are: less than 1 hectare, 1 to 3 hectares, 3 to 5 hectares, 5 to 10 hectares, 10 to 15 hectares, 15 to 20 hectares, 20 to 50 hectares, 50 to 100 hectares, 100 to 200 hectares, 200 to 500 hectares, 500 to 1000 hectares, 1000 to 2000 hectares, and more than 2000 hectares.

[24]One important caveat of this data, however, is that resource limitations prevent cadastral agencies from carrying out the updates during the established 5-year window for all the municipalities. In fact, Pinzón and Fonti (2007) find that only 31% of the municipalities were fully up-to-date in 2005. Yet, to the extent that the updates are not correlated with municipality's characteristics in general (Martinez, 2020), it is unlikely that my estimates are largely driven by differences in measurement error.

[25]The family farm unit was initially created by the Law 135 of 1961 to guide the allocation of vacant public lands. It represents the minimum plot size required to produce an income of three monthly minimum wages and a disposable income after paying land rent payments. This unit takes on different values depending on the type of agro-ecological zone and land use. Thus, the average unit for each town is calculated as the weighted mean across production systems and zones (Departamendo Nacional de Planeación, 2000).

times the family farm unit, (a, b) refer to the lower and upper bounds of the observed size ranges, and ω_i^a refers to the share of area in plots with a size of at least a hectares.[26] In addition to this measure, I also use this data to calculate the Gini index of landholdings, which is a measure of *overall* concentration across the whole plot distribution.

Additional municipal features: I compile a set of municipality characteristics using different data sources. First, I obtain information on administrative divisions and the town's average family farm unit from the National Department of Statistics (DANE). Second, I use administrative data from the National Memory Center to calculate measures of conflict intensity and the prevalence of forced displacement between 1993 and 2005.[27] Third, I digitize data on initial levels of urbanization, such as the total number of inhabitants and the share of the rural population, using the 1985 census. Finally, I calculate topographic measures on elevation and the average degree of terrain's inclination using the Data Elevation Model from NASA and the shapefiles of municipalities with 1993 boundaries. In contrast to other sources, these topographic measures are very precise as the pixel resolution is one arc-second (approximately 30 meters). This is particularly relevant for my analysis since it implies that the instrument I construct for land consolidation displays a considerable variation across towns.

Study population: The study population in this analysis consists of 590 municipalities across 21 *departments* of the country. These 21 departments correspond to 50% of the country's area and 95% of the national population.[28] My study sample accounts for three-fourths of the rural economies in these departments.[29] These towns are spread in similar proportions across lowlands, hills, and highlands, thereby representing the main agro-climatic regions in the country.

In Table 1, I present summary statistics that describe the main characteristics of the sample before the observed changes in land concentration (i.e. 1993). These municipalities are located about 79 kilometers from the department's capital and have a mean area of 537 square kilometers. In contrast to large cities, the population count was low and

[26]For instance, if the average family farm unit for the town is 32 hectares, my measure of large-farm consolidation equals the share of area in plots of at least 20 hectares. Since this measure based on size ranges is less precise than the one I would obtain with microdata, I plan to check whether the main results of the paper are robust to different definitions of ω_i^{large} in a future version of this draft.

[27]These indicators include the share of the forcefully displaced population, the number of murdered individuals, and the total number of attacks, incursions, and assaults on the civilian population perpetrated by illegal armed groups. For more details on this data, see Centro Nacional de Memoria Historica (2013).

[28]I exclude the municipalities from the departments of Amazonas, Arauca, Casanare, Caquetá, Chocó, Guainía, Guaviare, Putumayo, San Andrés, Vaupés, and Vichada for at least one of the following reasons: i) department was not part of the agricultural frontier in the 1990s, ii) rural areas consisted mostly of indigenous reservations and afro-colombian lands, iii) cadastral data was either non-existent or unreliable.

[29]The remaining 25% of rural towns do not have complete data for both years of analysis.

the the majority of workers worked in agricultural activities. These rural towns also had a low unemployment rate and a wide spread in the wage perceived by workers. While the average hourly wage was slightly above the minimum legal wage at COL$524, close to two-thirds of the workers were making less than that amount.[30]

Finally, the size threshold that defines a large farm has a mean of 220 hectares and varies widely across towns. For instance, while in some municipalities, a large farm has at least 800 hectares, in others, farms of 25 hectares are considered large. The share of area in large farms across municipalities was 29% on average and one-quarter of these towns had a share above 42%.

4.2 Trade Liberalization and Shift in Land Concentration

Colombia underwent a process of trade liberalization in the early 1990s. This liberalization ended an import substitution regime that lasted over forty years and was characterized by the gradual reduction of import tariffs, the enactment of several trade agreements, and the implementation of policies to promote exports. The average tariff in the whole economy went from 38.6% to 11%, and from 31.5% to 15% in the agricultural sector (Jaramillo, 1998). After the integration, the agricultural sector experienced a productive transformation and a change in land use. The area in pastures and cash crops increased by more than two million hectares, while the area to grow importable crops decreased (see Figure 6).

This productive transformation was accompanied by a general shift in land concentration. In some regions, farms were consolidated to produce land-intensive cash crops such as cattle, flowers, and oil palm.[31] In others, farms were fragmented to mitigate the impacts of the deterioration in the terms of trade. Overall, rural municipalities experienced an increase in the Gini index of landholdings during this period, and large-farm consolidation changed over 90% of the towns.[32]

Table 2 reports the changes in consolidation and rural employment in my sample between 1993 and 2005. Large-farm consolidation displayed a marginal decrease over this period and there was a wide variation in the direction and magnitude of this change across locations (see Figures 7 and 8).

[30] An hourly wage of COL$524 in 1993 is equivalent to COL$3,806 per hour in 2019 (U$1 per hour).

[31] These crops are usually produce at large-scale due to a high degree of vertical integration. Furthermore, cattle has a maximum carrying capacity per hectare that requires a minimum plot size threshold to render production profitable.

[32] Laskievic (2021) also finds an increase in the Gini index after the commodity price boom in Brazil during the 2000s.

4.3 Identification Strategy

To examine the impacts of large-farm consolidation, I use a 2sls approach that exploits the differential ability of the municipalities to respond to this trade-induced shock. In particular, I construct an instrument for the change in consolidation based on topographic features of the economy that influence the financial viability of production at a large scale. This instrument is defined as the average degree of inclination for the terrain in each municipality.[33] In my sample, the degree of inclination ranges from $1.5°$ to $64.8°$ and has an average of $29.7°$.

The rationale behind this instrument is that the construction and maintenance of infrastructure for large-scale production are cheaper in flatter terrains. For instance, export crops such as flowers and oil palm require greenhouses and irrigation systems. Likewise, flat landscapes are more attractive for mechanization and extensive cattle ranching, as the carrying capacity per hectare decreases with the gradient of inclination.[34] Declines in large-farm consolidation are also smaller in locations with lower degree of inclination, as the opportunity cost of fragmentation is higher. For instance, while coffee farms in the slopes are fragmented after declines in the international coffee price, coffee farms in the inter-Andean valleys are often transformed into cattle farms (Balcázar, 2003; García, 2003). This negative relationship between large-farm consolidation and the economy's degree of inclination is depicted in Figure 9.

A town's topography also influences crop suitability. Thus, one important threat to the exclusion restriction of this instrument is that locations with different crop portfolios faced distinct income and labor market shocks due to trade liberalization. For instance, economies that were suitable to produce cash crops experienced an improvement in their terms of trade, while economies that produced importable crops were negatively affected in terms of profitability. To address this concern, I compare contiguous municipalities of the same province (δ_p), which share similar crop suitability and are subject to the same governmental policies.[35]

Similarly, previous evidence suggests that the upsurge in conflict during this period likely had differential effects on labor markets of economies with distinct topography. On the one hand, conflict induced changes in agricultural production and labor supply (Arias

[33]This measure corresponds to the area-weighted average across all the raster cells that intersect with the municipality's surface. For more details on the data used to construct this measure, see Section 4.1.

[34]According to interviews in the field, the carrying capacity of cattle in flatlands is about three cows per hectare compared to two cows (or less) in the slopes.

[35]Provinces are department subdivisions that have been historically used to plan and develop environmental and territorial policies (DANE, 2014). There are 100 provinces in my sample with an average of eight municipalities per province.

et al., 2018; Fernández et al., 2014). On the other, the upsurge was more pronounced in the mountains as they provide a natural shelter for illegal groups (Centro Nacional de Memoria Historica, 2013). I account for this potential relationship by controlling for changes in forced displacement and trends in conflict-related measures such as homicides and the number of attacks (ΔC_{mp}).

For the analysis on unemployment and sectoral employment, I estimate equations of the form:

$$\begin{aligned} \Delta Y_{mp} &= \beta \Delta \hat{D}_{mp} + \delta_p + \alpha_1 \Delta C_{mp} + \Delta u_{mp} \\ \Delta D_{mp} &= \gamma S_{mp} + \delta_p + \alpha_2 \Delta C_{mp} + \Delta \eta_{mp} \end{aligned} \tag{6}$$

where ΔY_{mp} refers to the change in the outcome of interest between 1993 and 2005 for municipality m in province p, ΔD_{mp} refers to the change in large-farm consolidation, and S_{mp} refers to the terrain's degree of inclination. In all estimations, standard errors are clustered at the municipality level to account for serial correlation. To give an idea of the variation I use to estimate β, I show the spatial distribution of the instrument and its values after partialling out the fixed effects and covariates in Figure 10.

For the analysis on wages, I use repeated cross-sections of workers in rural municipalities. Thus, I estimate the following modified version of Equation 6:

$$\begin{aligned} Y_{imjt} &= a_m + \beta \hat{D}_{mjt} + \delta_{j,t} + \alpha_1 C_{mjt} + \lambda_1 X^{85}_{m,t} + u_{imjt} \\ D_{mjt} &= a_m + \gamma (S_{mj} \times T_t) + \delta_{j,t} + \alpha_2 C_{mjt} + \lambda_2 X^{85}_{m,t} + \eta_{mjt} \end{aligned} \tag{7}$$

where Y_{imjt} refers to the log hourly wage of worker i in municipality m, at time t, and T_t is a dummy variable that takes the value of one (zero) for the year 2009 (1998). These cross-sections include the subset of rural municipalities that were sampled in both years of the survey. Since only a few of these towns belong to the same province, I use department-year fixed effects to account for income changes induced by the change in the terms of trade ($\delta_{j,t}$). Hence, I also control for initial urbanization rates ($X^{85}_{m,t}$) to account for differential trends in development across towns of the same department.

In contrast to the analysis in Equations 6, I use a two-sample 2sls approach to estimate the Equations in 7.[36] This approach allows me to estimate the *first-stage* with the full sam-

[36] The two-sample 2sls approach was proposed by Angrist and Krueger (1995) as a procedure to obtain 2sls estimates using two independent samples; one for each stage. For more information on the consistency of this procedure, see Inoue and Solon (2010), Pacini and Windmeijer (2016), Choi et al. (2018), and Angrist and Krueger (1992).

ple of municipalities to improve the precision of these estimates.[37] I follow Pacini and Windmeijer (2016) to correct the standard errors of this two-step procedure and obtain estimates that are robust to heteroskedasticity.

The exclusion restriction in Equation 6 is that municipality's terrain inclination does not lead to different labor market trends across contiguous economies within the same province.[38] This assumption would be violated if the design and execution of public policies in a province depends on topography, or if the trade-induced income effects - associated with the production of certain crops- are not fully accounted for. In Table 3, I show that rural municipalities with distinct levels of terrain inclination had similar trends in urbanization and population growth before trade liberalization.[39] While the exclusion restriction in untestable, these results provide reassuring support for this assumption.

In this case, β identifies the average marginal effect on the subpopulation of economies that respond to encouragement from the instrument (i.e. compliers).[40] This subpopulation comprises the towns where the shift in land consolidation was driven by the physical and financial ability of production at scale.

In the case of Equation 7, the exclusion restriction is stronger as the larger variation in agro-climatic conditions across municipalities of the same department imply that crop-specific income effects are not fully accounted for . In line with this, Table 4 shows that towns with different terrain's inclination within the same department displayed differences in population growth before trade liberalization. Therefore, the results of the analysis on wages should be regarded with caution.

4.4 Results

Table 5 shows the results on the structure of rural employment and unemployment rates. Panel A reports the first stage relationship and the reduced form effects of the municipality's inclination gradient. Panel B reports the corresponding 2sls estimates for the

[37] Naturally, the second stage is estimated using only the subset of towns with data on workers' wage.

[38] Formally, $E(s_{mp}\Delta u_{mp}|\Delta C_{mp},\delta_p)=0$. This assumption is weaker than the one required for the within estimator, which states that the *idiosyncratic* component of land consolidation across municipalities of the same province is not correlated with labor market shocks; i.e. $E(\Delta D_{mp}\Delta u_{mp}|\Delta C_{mp},\delta_p)=0$.

[39] These two variables are closely related to changes in sectoral employment and labor supply in a local economy. I will analyze pre-trends on my outcomes of interest once I am granted re-access to the microdata of the 1985 population census at the Colombian National Department of Statistics.

[40] Monotonicity is an additional assumption that is required to interpret β as the local average marginal effect of land consolidation on the outcomes of interest. This assumption, untestable in nature, implies that while increasing the average slope can either encourage land consolidation or have no effect at all, it cannot discourage consolidation relative to lower slope values (Kennedy et al., 2019).

outcomes of interest and the Kleibergen-Paap F-statistic that tests for the first-stage.[41] I also report weak instrument-robust confidence sets to avoid bias due to pre-testing for the instrument's relevance (Andrews et al., 2019).

The first-stage results confirm the negative relationship between the terrain's inclination and the change in large-farm consolidation. This relationship is significant at 1% and implies that a one standard deviation increase in the terrain's inclination is associated with a decrease in large-farm consolidation of three percentage points. The reduced-form estimates are also statistically significant at 1% and are close in magnitude to the first-stage estimates, suggesting that the two patterns are closely related (Angrist and Pischke, 2008).

The 2sls results indicate that rural economies with an increase in large-farm consolidation experienced a decline in the share of agricultural labor and a sizeable increase in unemployment. These estimates are significant at the 1% and remain unchanged when using the Anderson-Rubin inference procedure, suggesting that the results are not driven by a potential weak relationship in the first stage. To illustrate the magnitude of the estimates, consider the average Colombian municipality which in 1993 had a share of agricultural workers of 67% and an unemployment rate of 2.9%. If this municipality experienced a one standard deviation increase in consolidation –corresponding to a twelve percentage point rise in the share of area in large farms–, the agricultural employment share would fall ten percentage points, and the unemployment rate would increase 14 points.

I now explore how large-farm consolidation affected the wage of rural workers. Table 6 reports the two-sample 2sls results and provides support for the consistency of these estimates since I cannot reject the equality of the first-stage coefficient across the two samples used. The initial results suggest that the effect on wages is negative and marginally significant at 10%. However, once I account for weak-instrument robust inference, the significance of the estimate vanishes, suggesting that large-farm consolidation did not have any significant effect on wages. Since these estimates do not properly control for income effects induced by the change in the terms of trade, it is important to regard them with caution. Additional results suggest that not accounting for such income trends may underestimate the impact on workers' wages (see Section 4.5).

Taken together, the sizeable estimates on unemployment and the results on the wage suggest that the net effect of consolidation on workers' income is negative. My estimates on sectoral employment imply that land consolidation explains 72% of a standard deviation in the decline in farm employment between 1993 and 2005 across all municipalities.[42]

[41] In the case of one endogenous regressor, the Kleibergen-Paap statistics is equivalent to the effective first-stage F statistic proposed by Montiel-Olea and Pflueger (2013).

[42] This measure is calculated dividing the standardized effect of consolidation on the share of farmworkers (-0.10) by a standard deviation in the observed change of farmworkers share between 1993 and 2005 (0.14).

4.5 Robustness Exercises

Additional controls: As discussed in Section 4.3, one potential threat to the exclusion restriction is the upsurge in conflict during the period analysis. Historical accounts suggest that conflict and forced displacement had different intensities across municipalities in the lowlands and the slopes (Centro Nacional de Memoria Historica, 2013, 2012). In my preferred specification, I control for measures on the upsurge of conflict. However, as Table A1 shows, my main estimates are robust to the exclusion of these covariates, suggesting that municipalities of the same province had similar exposure to these shocks regardless of their topography. In columns 3 and 6, I extend my preferred specification to control for potential trends driven by distinct levels of urbanization before the trade liberalization took place. While the estimates on unemployment decrease slightly, they remain significant at 1%.

Income effects induced by trade-liberalization: My preferred specification compares municipalities of the same province to account for the potential correlation between terrain's inclination -the instrument-, crop suitability, and income effects. In Table A2, I show that province fixed effects play an important role in accounting for the expected bias generated by these income effects. The 2sls estimates that compare towns in the lowlands and the mountains without conditioning on province would have predicted a decline in unemployment rates after consolidation, since the economies in the lowlands experienced a general improvement in their terms of trade (Jaramillo, 2002).

This table also shows that province fixed effects do a better job in accounting for the expected bias on unemployment rates than department fixed effects. This suggests that my main findings on the effects of large-farm consolidation on wages may underestimate the real effect.

Alternative standard errors: In addition to inference procedures for weak instruments, the main results are robust to different types of intra-cluster correlation. As shown in Table A3, the results are practically unchanged when using two-way clustered standard errors by municipality and province-year as well as municipality and department-year. The latter allows for correlation of the municipality's error across time and the error within-time correlation across municipalities of the same department.[43]

[43] To conduct this analysis, I estimate the panel fixed effects version of Equation 6 where the instrument is given by the interaction of the municipality's inclination terrain and the time trend, $Z_{mpt} = S_{mp} \times T_t$.

4.6 Interpretation of Results to the Light of the The Model

Overall, my findings indicate that consolidation led to a decrease in the demand for farmworkers and an absolute reduction in the demand for rural labor. These results are consistent with the model's predictions when the pull response in the nonfarm sector is small relative to the push response in the farms. That is, the increase in local consumption, and thereby labor demand in the nonfarm sector, is not large enough to absorb the workers that are leaving the farms.

While the reallocation of labor across space is another mechanism through which local labor markets adjust in the long-term (Breza et al., 2021; Asher et al., 2021; Bustos et al., 2016), my results on unemployment suggest that migration was not large enough to offset the decrease in labor demand after consolidation. These findings are consistent with the low levels of integration across rural labor markets during the 1990s (Nupia, 1997) and support previous empirical results on the delayed adjustment of labor markets to economic shocks (Dix-Carneiro and Kovak, 2019; Dix-Carneiro, 2014; Autor et al., 2014; Artuç et al., 2010).

Due to data limitations, I cannot directly test the effect of land consolidation on local consumption to assess the importance of non-homothetic consumption growth as profits get concentrated. However, as an indirect analysis, I estimate Equation 6 for a subset of economies where local multiplier effects are expected to be large. In particular, towns that are most suitable to produce coffee, a crop that has historically been grown by producers who reside in their farms or the local economies (see Table A4). This descriptive analysis indicates that the effect of consolidation on unemployment was smaller and less significant across family-oriented production regions, suggesting that local consumption is driving part of the absolute decrease in labor demand.

In work in progress, I calibrate the model using farm-level data to quantify the potential effects of the pending land reform in Colombia. I will also use these calibrated parameters to assess how much of these effects are driven by non-homothetic consumption growth.

5 Conclusions and Discussion

This paper provides theoretical and empirical evidence of the effect of large-farm consolidation on rural labor markets in Colombia. The empirical findings indicate that consolidation can lead to a reallocation of labor away from agriculture within rural economies along with a decrease in workers' earnings. These results imply a reduction in local labor demand after consolidation, and are consistent with a model that features differences in farm labor intensity and non-homothetic consumption growth in the nonfarm sector. My findings on workers' earnings imply that migration was not large enough to offset the decrease in labor demand in the medium term, which suggests the existence of barriers to labor mobility across space.

The results in this paper have two main implications for the analysis of land policies. First, they shed light on the distributional impacts of large-farm consolidation across individuals as rural workers may experience a decrease in income despite productivity gains. Second, they imply that the reallocation of workers out of the farms can be accompanied by a decline in rural wages. This relationship is the opposite sign than we usually observe with the process of structural transformation and is consistent with recent evidence on the impacts of such transformation across space (Eckert and Peters, 2018).

While this paper is a step toward understanding the effect of large-farm consolidation on rural labor markets, it opens several questions for future research. For example, what is the contribution of each of the mechanisms? And how do the effects vary under different levels of geographic labor mobility? The theoretical framework that I propose can also be used to quantify the impact of the upcoming land reform on the structural transformation of rural Colombia. This is an extension I am currently working on.

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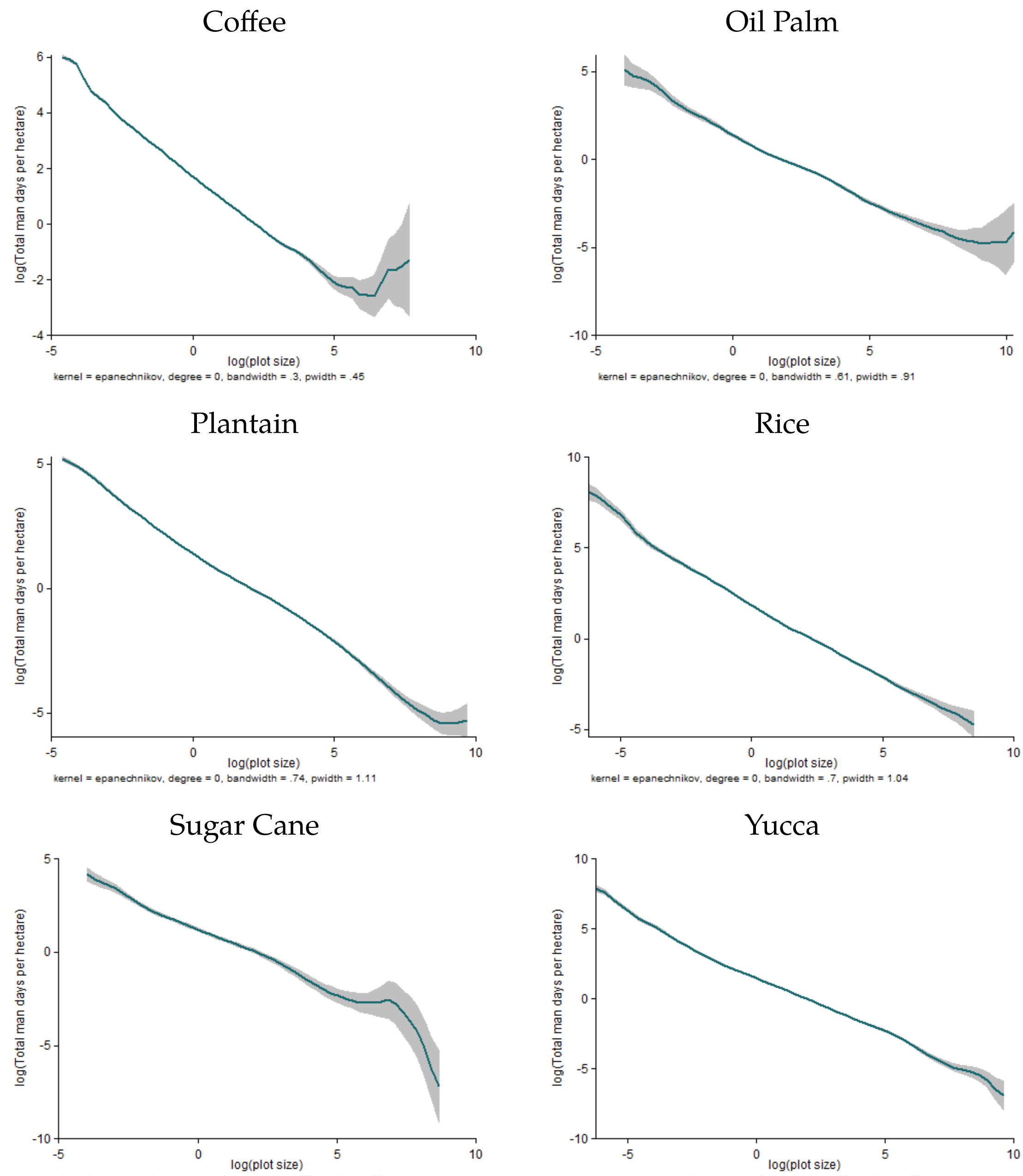
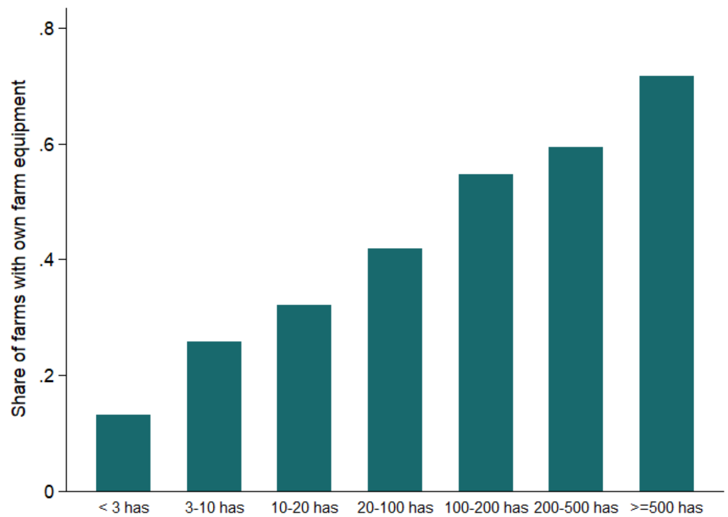
Figures and Tables

Figure 1: Labor Intensity By Plot Size



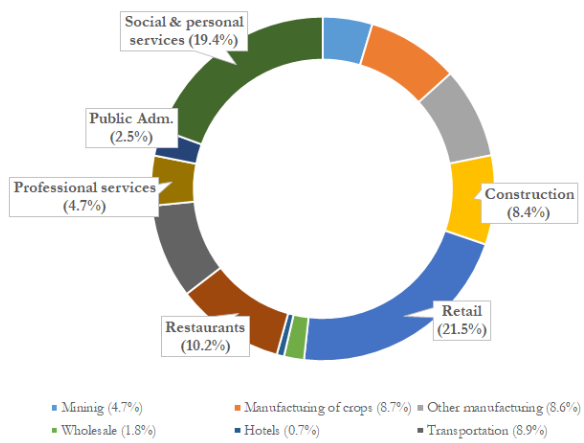
Notes: Own illustrations using data from the 2014 National Agricultural Census.

Figure 2: Equipment Ownership By Farm Size



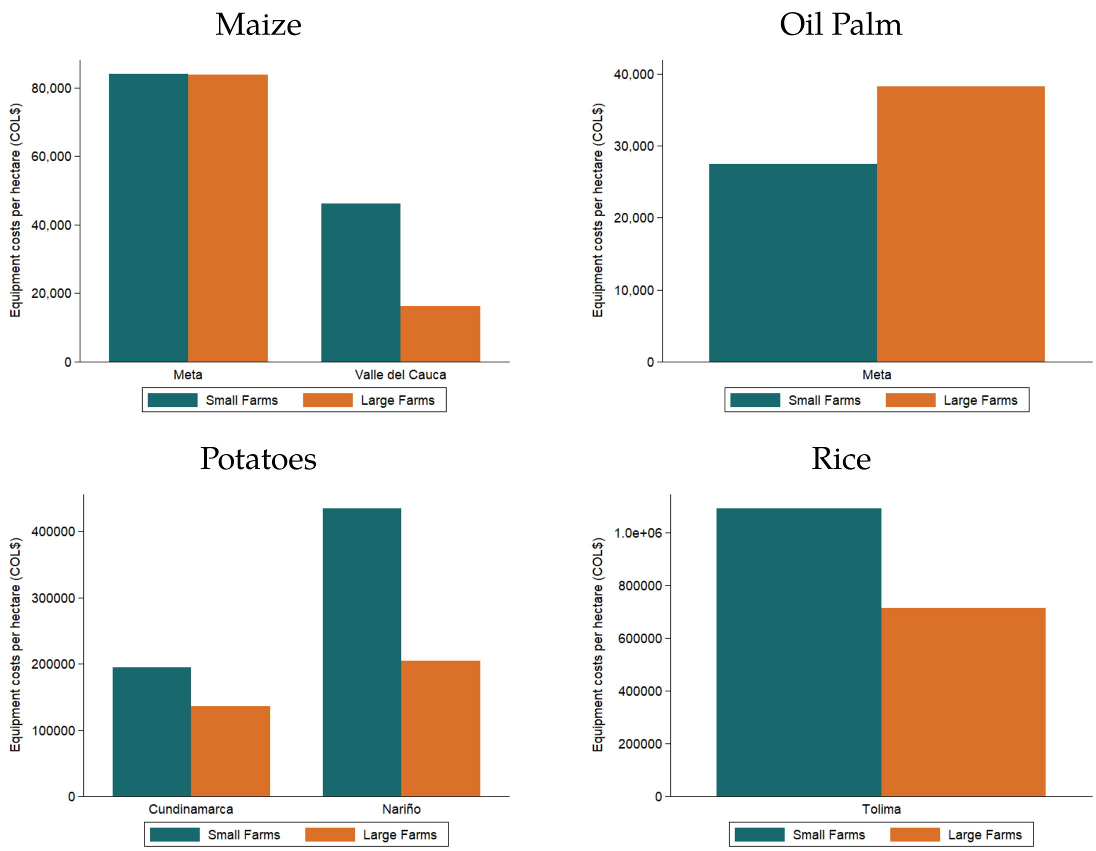
Notes: Own illustrations using data from the 2014 National Agricultural Census.

Figure 3: Distribution of Nonfarm Employment



Notes:. Own illustrations using data from the 2016 National Household Survey (GEIH)

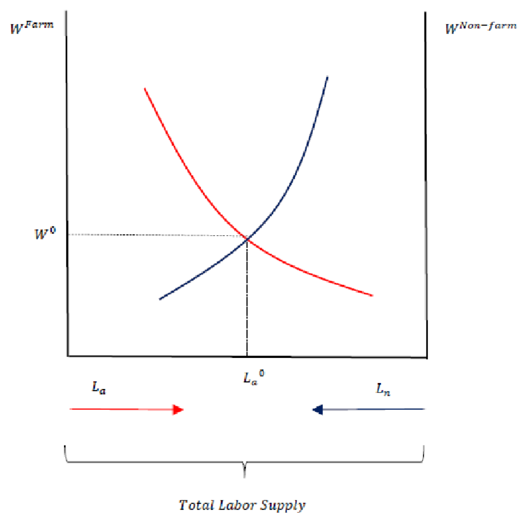
Figure 4: Equipment Costs Per Hectare, By Farm Size



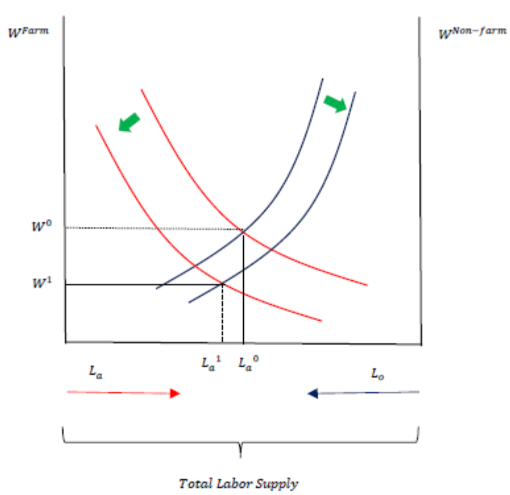
Notes: Own figures based on the data reported in Perfetti et al. (2012). Equipment costs per hectare are measure in Colombian pesos of 2012. Small farms refer to the farms that are at most one family farm unit in size, while large farms refers to farms that are more than one family farm unit in size. For details on the family farm unit measure, see Section 4.1.

Figure 5: Overall Effect on Equilibrium Wage: An Illustration

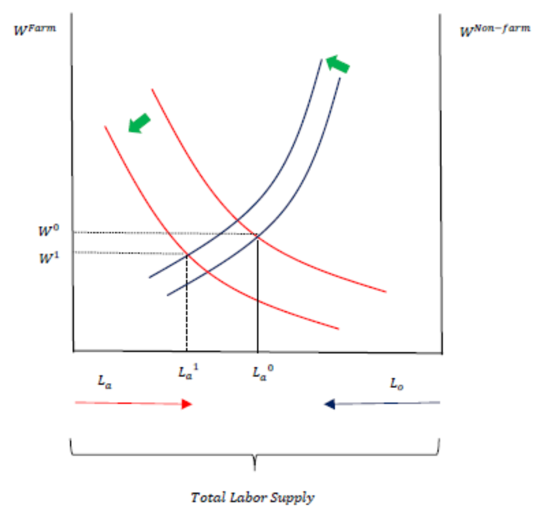
Panel A. The Rural Labor Market



Panel B: Unambiguous Effect

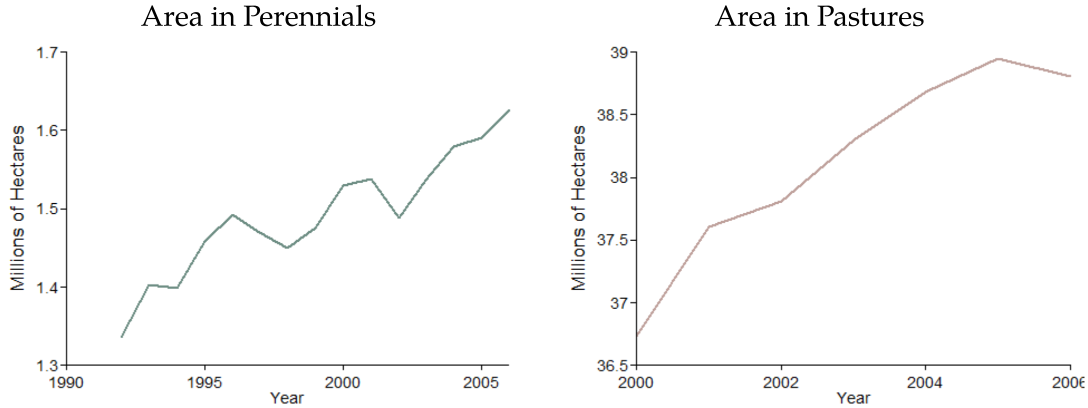


Panel C: Ambiguous Effect



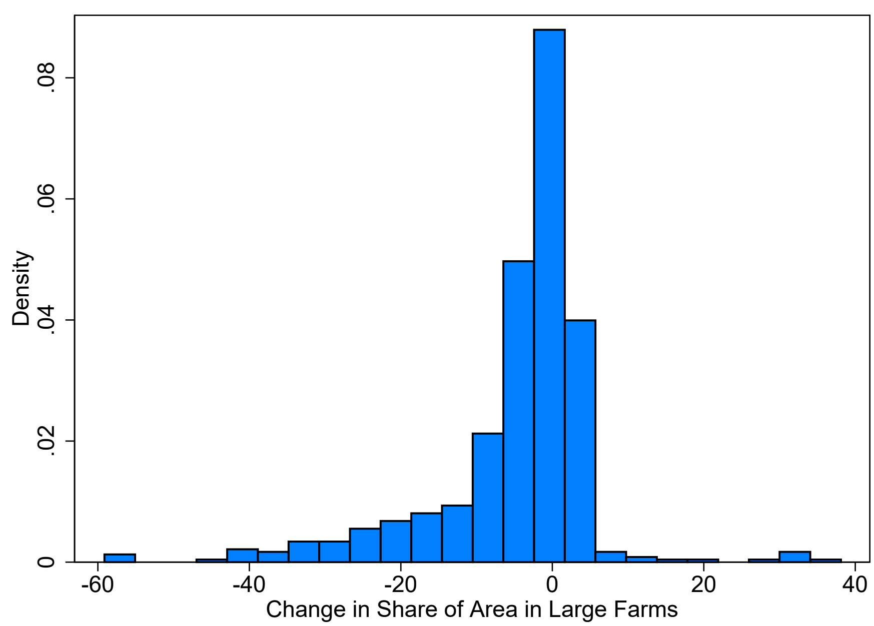
Notes: Own illustration.

Figure 6: Area in Land-Intensive 1993-2005



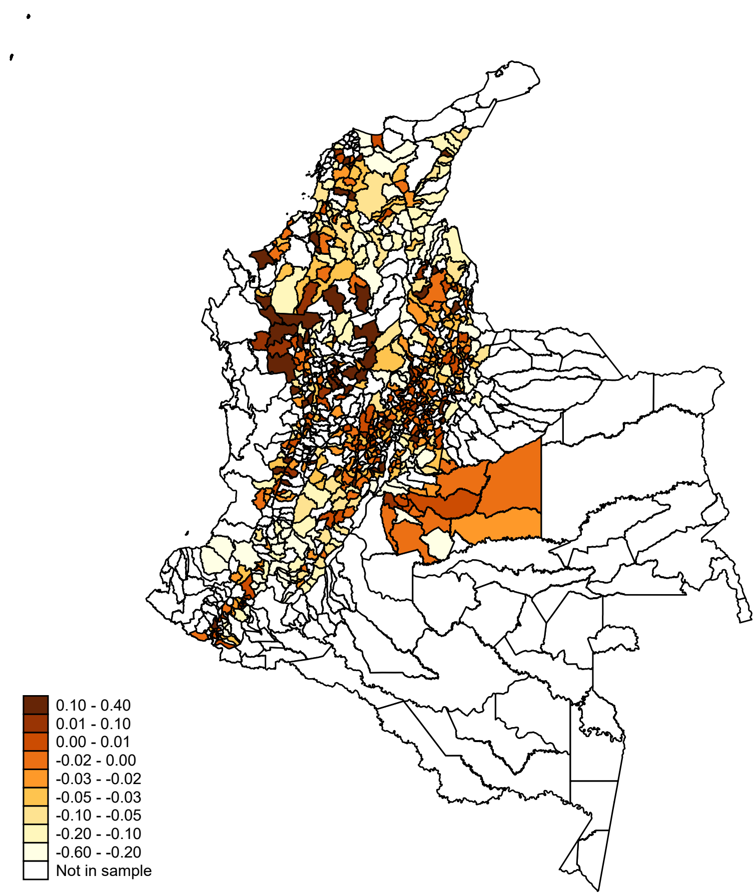
Notes: Own illustrations using data from the Municipal Agricultural Evaluations.

Figure 7: Shift in Large-Farm Consolidation Across Municipalities



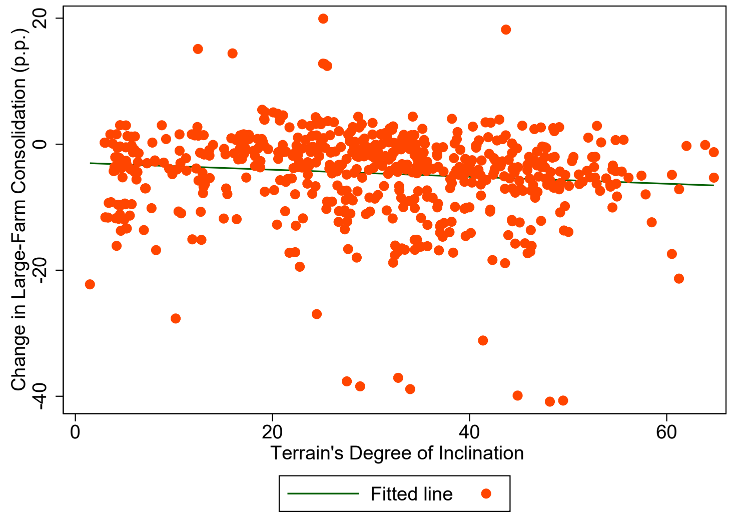
Notes: This figure displays the change in the share of area in large farms (in percentage points) for rural municipalities between 1993 and 2005. Own calculations using cadastral data.

Figure 8: Spatial Variation in Consolidation Shift



Notes: This map displays the change in the share of area in large farms (in percentage points) for rural municipalities between 1993 and 2005. Own calculations using cadastral data.

Figure 9: Change in Large-Farm Consolidation & Terrain's Inclination

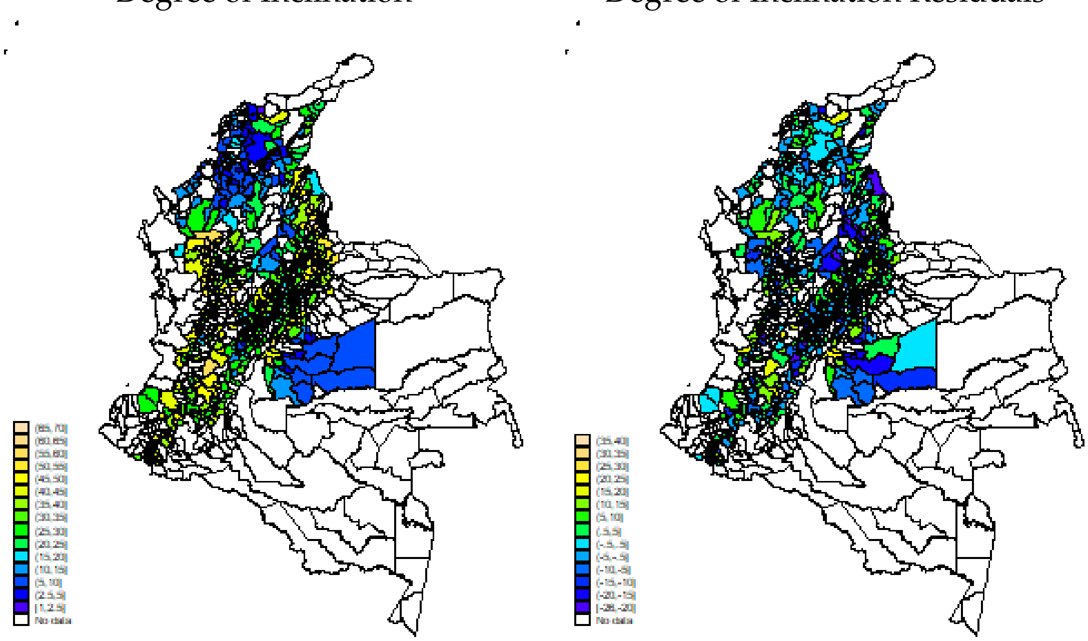


Notes: This figure depicts the fitted values of a regression of the change in consolidation on the terrain's inclination and province fixed effects.

Figure 10: Spatial Variation in Terrain's Inclination

Degree of Inclination

Degree of Inclination Residuals



Notes: These maps display the spatial distribution of the municipality's terrain inclination (in degrees) and its values after partialling out province fixed effects and the change in conflict-related controls 1993-2005.

Table 1: Main Characteristics of The Study Population in 1993

	N	Mean	S.D.	Min	p25	p75	Max
Time-invariant characteristics							
Total area (km2)	590	536.7	1,121.7	20.0	127.0	541.0	17,536.0
Distance to departmen's capital (km)	590	78.7	47.7	9.3	44.2	102.8	276.0
Family farm unit (ha)	590	22.0	14.1	2.5	13.1	27.3	125.6
Terrain's inclination (degrees)	590	29.7	14.5	1.5	19.2	40.7	64.8
Time-variant characteristics (1993)							
Total population	590	15,543	14,865	1,277	6,389	19,865	171,936
Share rural population (%)	590	68.7	18.5	4.8	58.4	82.8	97.2
Share of farm employment (%)	590	66.6	17.5	0.7	56.6	80.7	95.9
Unemployment rate (%)	590	2.5	2.2	0.0	1.0	3.5	17.9
Hourly wage (1993 COL$)[†]	1,366	524.1	613.5	3.4	102.2	687.5	6642.9
Gini of landholdings	590	0.38	0.16	0.04	0.26	0.51	0.90
Share of area in large farms (%)	590	29.1	21.4	0.0	11.3	42.4	99.4

Notes: (†) The statistics on hourly wage refer to the wage workers in the 1998 National Household Survey. The average hourly wage of $\$524$ pesos in 1993 corresponds to $\$3,806$ pesos in 2019, which is approximately equivalent to an hourly wage of U$1. See Sections 4.1 for details on data sources and definitions.

Table 2: Changes in Main Variables 2005- 1993

	1993		$\Delta_{2005-1993}$	
	Mean	SD	Mean	SD
Share of agricultural workers	0.666	0.174	-0.092	0.138
Unemployment rate	0.025	0.022	0.080	0.123
Gini of landholdings	0.386	0.157	0.006	0.079
Share of area in large farms	0.291	0.214	-0.059	0.129
Number of conflict-related events since 1993	1.017	1.951	22.692	31.833
Number of homicides since 1993	148.33	265.73	346.63	509.04
Number of displaced individuals since 1993 (expelled)	311.71	820.02	3505.02	7802.53
Number of displaced individuals since 1993 (received)	93.58	307.40	1850.23	4318.27

Notes: The number of municipalities included is 590. See Section 4.1 for details on data sources and definitions.

Table 3: Pre-Trends Test for Analysis on Sectoral Employment & Unemployment Rate

	Share Rural Pop. (Δ_{85-93})		Total Population (Δ_{85-93})	
	(1)	(2)	(1)	(2)
Terrain's Inclination (degrees)	0.0001	0.0001	-31.39**	-20.62
	(0.0003)	(0.0004)	(14.46)	(14.57)
Province fixed effects	✓	✓	✓	✓
Conflict-related events (Δ_{85-93})		✓		✓
Number of municipalities	576	576	576	576

Notes: OLS estimates of the (Δ_{85-93}) in share of rural population and total population on the instrument before the observed change in land consolidation. These variables measure urbanization levels and are considered proxy variables for the main outcomes of interest. Standard errors are clustered at the municipality level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Pre-Trends Test for Analysis on Log Hourly Wage

	Share Rural Population (Δ_{85-93})		Total Population (Δ_{85-93})	
	(1)	(2)	(1)	(2)
Terrain's Inclination (degrees)	0.00009	0.00001	-48.93***	-36.03***
	(0.00025)	(0.00024)	(13.97)	(10.41)
Department fixed effects	✓	✓	✓	✓
Conflict-related covariates (Δ_{85-93})		✓		✓
Number of municipalities	576	576	576	576

Notes: OLS estimates of the (Δ_{85-93}) in share of rural population and total population on the instrument before the observed change in land consolidation. These variables measure urbanization levels and are considered proxy variables for the main outcomes of interest. Standard errors are clustered at the municipality level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Large-Farm Consolidation, Sectoral Employment & Unemployment Rate

Panel A. First Stage and Reduced Form Estimates			
	Share Area in Large Farms (Δ_{05-93}) (1)	Share Farm Employment (Δ_{05-93}) (2)	Unemployment Rate (Δ_{05-93}) (3)
Terrain's inclination (degrees)	-0.00239***	0.00186***	-0.00267***
	(0.000568)	(0.000656)	(0.000443)
Panel B. 2sls Estimates			
Share area in large farms (Δ_{05-93})		-0.777***	1.118***
		(0.301)	(00.309)
Standardized effect		-0.100	0.144
First Stage Results:			
Kleibergen-Paap F-statistic		17.69	17.69
Weak-Instrument Robust Inference:			
Anderson-Rubin P-value		0.004	0.000
Anderson-Rubin Confidence Set (95%)		[-1.59,-0.35]	[0.68,2.05]

Notes: 2sls estimates using Equation 6. The number of municipalities in these estimations is 590. All the specifications include province fixed effects and conflict-related covariates. Standard errors are clustered at the municipality level. The standardized effect is calculated by multiplying the coefficient of interest by one standard deviation of the change in large-farm consolidation (see Table 2). The null hypothesis of the Anderson-Rubin test is that the effect of land consolidation on the respective outcome is zero. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

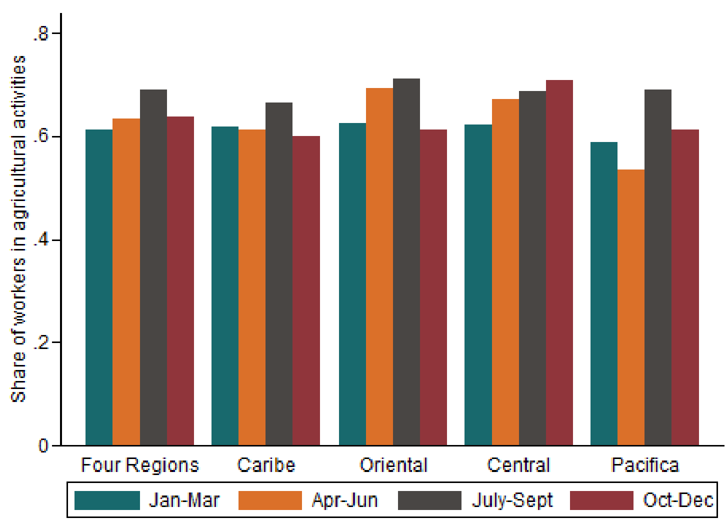
Table 6: Large-Farm Consolidation and Log Hourly Wage (TS2sls)

	(1)	(2)
Share of area in large farms	-2.946	-3.249*
	(1.985)	(1.967)
Standardized effect	-0.370	-0.409
Control variables 1985	✓	✓
Conflict-related covariates		✓
First Stage Results:		
Kleibergen-Paap F-statistic	16.857	16.859
Test of equality of coefficients (pval)†	0.670	0.645
Weak-Instrument Robust Inference:		
Anderson-Rubin P-value	0.211	0.169
Anderson-Rubin Confidence Set (95%)	[-8.53,1.69]	[-8.70,1.26]

Notes: TS2sls estimates using Equation 7. The number of observations is 2,529. All the specifications include municipality fixed effects, department-year fixed effects, and interactions of both the population size and the share of rural population in 1985 with year fixed effects. Standard errors are robust to heteroskedasticity. The second row in *First Stage Results* tests the null hypothesis that the first-stage coefficient is equal across both samples, which is an additional assumption for the consistency of the two-sample 2sls estimator (†). The null hypothesis of the Anderson-Rubin test is that the effect of consolidation on the hourly wage is zero. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A Appendix Tables and Figures

Figure A1: Share of Agricultural Employment in Rural Areas, by Quarter and Region



Notes: Own illustrations using data from the National Household Surveys.

Table A1: Large-Farm Consolidation, Sectoral Employment & Unemployment Rate: Different Set of Covariates

	Share of Agricultural Emp. (Δ_{05-93})			Unemployment Rate (Δ_{05-93})		
	(1)	(2)	(3)	(1)	(2)	(3)
Share area large farms (Δ_{05-93})	-0.777***	-0.780***	-0.845***	1.118***	1.129***	0.856***
	(0.301)	(0.293)	(0.309)	(0.309)	(0.307)	(0.246)
Standardized effect	-0.100	-0.100	-0.109	0.144	0.145	0.110
Conflict-related events (Δ_{05-93})	✓		✓	✓		✓
Population in 1985 (logs)			✓			✓
First Stage Results:						
Kleibergen-Paap F-statistic	17.69	18.69	16.37	17.69	18.69	16.37
Weak-Instrument Robust Inference:						
Anderson-Rubin P-value	0.004	0.002	0.001	0.000	0.000	0.000
A-R Confidence Set (95%)	[-1.58, -0.35]	[-1.57, -0.36]	[-1.34, -0.11]	[0.68,2.05]	[0.69,2.05]	[0.51,1.67]
N	590	590	576	590	590	576

Notes: 2sls estimates using different covariates in Equation 6. Results in (1) refer to main specification. All specifications include province fixed effects and standard errors are clustered at the municipality level. The null hypothesis of the Anderson-Rubin test is that the effect of consolidation on the respective outcome is zero. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2: Large-Farm Consolidation, Sectoral Employment & Unemployment Rate: The Importance of Province Fixed Effects

	Share of Agricultural Emp. (Δ_{05-93})			Unemployment Rate (Δ_{05-93})		
	(1)	(2)	(3)	(1)	(2)	(3)
Share area large farms (Δ_{05-93})	1.198***	-0.591**	-0.777**	-0.650***	1.034***	1.118***
	(0.169)	(0.277)	(0.301)	(0.100)	(0.315)	(0.309)
Standardized effect	0.154	-0.076	-0.100	-0.084	0.133	0.144
Department fixed effects		✓			✓	
Province fixed effects			✓			✓
First Stage Results:						
Kleibergen-Paap F-statistic	87.61	17.65	17.69	87.61	17.65	17.69
Weak-Instrument Robust Inference:						
Anderson-Rubin P-value	0.000	0.024	0.004	0.000	0.000	0.000

Notes: 2sls estimates using different sets of fixed effects in Equation 6. Results in (3) refer to main specification. The number of municipalities in these estimations is 590. All the specifications include conflict-related covariates and standard errors are clustered at the municipality level. The null hypothesis of the Anderson-Rubin test is that the effect of consolidation on the respective outcome is zero. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A3: Large-Farm Consolidation, Sectoral Employment, & Unemployment Rate: Different Types of Standard Errors

	Share of Agricultural Emp.			Unemployment Rate		
	(1)	(2)	(3)	(1)	(2)	(3)
Share of area in large farms	-0.777***	-0.777**	-0.777**	1.118***	1.118***	1.118***
	(0.301)	(0.347)	(0.341)	(0.309)	(0.405)	(0.423)
Standardized effect	-0.100	-0.100	-0.100	0.144	0.1441	0.144
Standard errors:						
Cluster municipality level	✓			✓		
Two-way cluster mun & depto-year		✓			✓	
Two-way cluster mun & prov-year			✓			✓
First Stage Results:						
Kleibergen-Paap F-statistic	17.69	12.19	9.06	17.69	12.19	9.06
Weak-Instrument Robust Inference:						
Anderson-Rubin P-value	0.004	0.014	0.010	0.000	0.001	0.000
A-R Confidence Set (95%)	[-1.58, -0.35]	[-2.04, -0.28]	[-2.24, -0.29]	[0.68,2.05]	[0.54,2.72]	[0.65,3.46]

Notes: 2sls estimates using a fixed effects version of Equation 6. Results in (1) refers to main specification. The number of municipalities in these estimations is 590. All the specifications include municipality fixed effects, province-year fixed effects and conflict-related covariates. The null hypothesis of the Anderson-Rubin test is that the effect of consolidation on the respective outcome is zero. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A4: Large-Farm Consolidation and Unemployment Rate: By Expected Strength of Local Multiplier Effects

	Full Sample	Expected Local Mult. Effects	
		Strong	Weak
Share area large farms (Δ_{05-93})	1.118***	0.857*	1.041***
	(0.309)	(0.470)	(0.320)
Standardized effect	0.144	0.110	0.134
Average unemployment rate in 1993	2.5%	1.9%	2.7%
Kleibergen-Paap F-statistic	17.69	7.84	14.52
Weak-Inst. Robust Inference:			
Anderson-Rubin Conf. Set (95%)	[0.678, 2.049]	[0.187, 3.015]	[0.584, 2.11]
N	590	133	457

Notes: 2sls estimates using Equation 6. Outcome is (Δ_{05-93}) unemployment rate. The subsample with expected strong multiplier effects include economies between 1,200 and 1,800 m.a.s.l, which corresponds to towns with high suitability for coffee production. All specifications include province fixed effects and conflict-related covariates. Standard errors clustered at municipality level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

B Preliminaries of Calibration Analysis

This section presents preliminary results of the calibration procedure to identify the structural parameters of the model proposed in Section 3 related to the production technologies and preferences. The model does a good job matching the targeted moments and untargeted moments related to the distribution of plots and area across farms, but needs to be tuned to better match untargeted relationships on input intensity across the whole farm size distribution. Once this analysis is finalized, I will run several counterfactual experiments to quantify the implications of the future redistributive land policy in Colombia.

B.1 Calibration

I calibrate the model based on the Colombian rural economy. The parameters to calibrate are technological parameters, preference parameters, distributional parameters, and endowments. The calibration strategy follows two steps. First, I calibrate some parameters externally based on values taken from the literature. Some of them are assigned directly, and others are set independently of the model's equilibrium outcomes. Then, I calibrate the remaining parameters using the model's structure to match targeted moments at the aggregate and farm level.

Parameters calibrated externally: Table B5 summarizes the parameters that are calibrated based on values from the literature. I normalize productivity and the output price in agriculture (A, p_a) to 1 and set $\gamma = 0.40$ based on the land shares estimated by Avila and Evenson (2010).[44] The relative weights of consumption goods in preferences are set based on the empirical estimates of the structural transformation literature (Herrendorf et al., 2013). In particular, I set ω_a equal to the weight of agricultural consumption and ω_n to the weight of consumption in services. The motivation for using estimates from the service sector to calibrate ω_n is that the local nonagricultural good in the model is non-tradable.

Based on the estimates of Gáfaro et al. (2014), I set the share of landed agents in the economy equal to 0.42. In addition, I assume that the distribution of land among these agents is Pareto, which is a standard way to model land heterogeneity in the development literature: $F(h) = 1 - \left(\frac{h_m}{h}\right)^{\tau}$.[45] Given this distribution, I set $\tau = 1.07$ and $h_m = 1.09$ to match a Gini coefficient of 0.88 and an average farm size of 16.9 hectares.[46] Using the agricultural census, I estimate the total number of farmland hectares at $H = 34.2$ million. Thus, to match a farmland-to-labor ratio of 7.03, I set $L = 4.863$ million.[47] This latter value is in line with recent rural workforce estimates using the national household surveys (Otero-Cortés, 2019). Finally, I set $r = 7\%$, which is the average real interest rate in the

[44] This parameter value is obtained as the area-weighted average of the land share in crop production (0.23) and livestock raising (0.44) in Colombia. The land share for crops is close to that of Peru (Sotelo, 2020), a country with a similar crop portfolio, and is smaller than Brazil's share (Pellegrina, 2020), characterized for production at a larger scale.

[45] See, for instance, Bazzi (2017), Carter and Kalfayan (1989), and Eswaran and Kotwal (1986).

[46] This farm size value is calculated using data from the agricultural census and is similar to the one estimated by Hamann et al. (2019).

[47] Given the Pareto distribution, the farmland-to-labor ratio is $\frac{H}{L} = \theta \frac{\tau h_m}{(\tau - 1)}$.

Colombian economy over the last decade.

Table B5: Parameters Calibrated Externally

Description	Paramater	Value
Productivity in agriculture	A	1.000
Price agricultural good	p_a	1.000
Land share of income	γ	0.398
Weight agricultural consumption	ω_a	0.020
Weight local nonagricultural consumption	ω_n	0.810
Share of landed agents	θ	0.416
Pareto distribution (shape)	τ	1.069
Pareto distribution (scale)	h_m	1.091
Aggregate farmland	H	34,207
Aggregate labor	L	4,863

Notes: The units for aggregate farmland and labor are thousand of hectares and individuals, respectively.

Table B6: Parameters Calibrated Using The Structure of The Model

Paramater	Value	Moment	Target	Model
η	0.871	Labor cost share	0.36	0.31
ρ	0.985	Ratio of labor per hectare (smallest/largest farm)	240	239
ν	0.171	Capital cost ratio (large/small farms)	0.77	0.99
$\bar{c_a}$	0.900	Expenditure share in agriculture	0.31	0.35
$p_c\bar{c_c}$	1.64E-05	Expenditure share in nonagricultural tradables	0.13	0.12

Notes: The target value for the labor cost share is taken from Avila and Evenson (2010). The expenditure shares are calculated using the households' budget survey, labor per hectare is calculated using the agricultural census, and the capital cost ratio is calculated using data from Perfetti et al. (2012).

Parameters calibrated using the structure of the model: Five parameters are jointly calibrated to match five aggregate moments from the Colombian data. The calibrated parameters are the relative importance of labor to capital, the determinants of the elasticity of substitution and capital pricing, and the non-homothetic parameters. Table B6 summarizes the parameter values and the moments used in the calibration. For each parameter, I also present the moment's target value and its respective model counterpart. I discuss each of these in turn.

The moments associated with the non-homothetic parameters $\bar{c_a}$ and $p_c\bar{c_c}$ are measured using the rural component of the National Households' Budget Survey.[48] The targeted

[48]The quantitative exercise discussed in this section does not require the identification of $\bar{c_c}$ and p_c separately. Further, since prices are the same for everyone, expenditure in consumption is proportional

moments are the aggregate share of final expenditure in agricultural goods and nonagricultural tradable industries.[49]

In addition to these moments, I select the parameter that determines the nonlinearities in capital pricing ν to match the ratio of capital costs between large and small farms. This ratio is calculated using data from the study conducted by Perfetti et al. (2012), which reports production costs by farm size for four main crops in the country: oil palm, potatoes, rice, and maize.[50] The target value of 0.86 is calculated as the area-weighted average across all crop-specific ratios. Finally, the relative importance of labor to capital in production η is selected to match the labor cost share in agriculture estimated by Avila and Evenson (2010). This target is calculated as the area-weighted average of the labor cost share for crops and livestock farming and takes a value of 0.36.

to quantity consumed. To identify $p_c\bar{c_c}$, I use the following transformation of the preferences: $u(c) = \omega_a log(c_a - \bar{c_a}) + \omega_n log(c_n) + \omega_c log(p_c c_c + p_c\bar{c_c}) - log(p_c)$.

[49] The tradable aggregate expenditure share is computed using the total monthly household expenditure in restaurants and hotels, home furniture, alcoholic beverages, clothing, and footwear.

[50] These four crops account for 42% of the national cultivated area. A future version of this draft will include cost data from coffee production, which is the crop with largest cultivated area at 16%.