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Working Paper

Land Accumulation Dynamics in Developing Country Agriculture

IDB Working Paper Series, No. IDB-WP-519

Provided in Cooperation with:

Inter-American Development Bank (IDB), Washington, DC

Suggested Citation: Henderson, Heath; Corral, Leonardo; Simning, Eric; Winters, Paul (2014) : Land Accumulation Dynamics in Developing Country Agriculture, IDB Working Paper Series, No. IDB-WP-519, Inter-American Development Bank (IDB), Washington, DC, <https://hdl.handle.net/11319/6560>

This Version is available at:

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2014

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Henderson, Heath

Land accumulation dynamics in developing country agriculture / Heath Henderson, Leonardo Corral, Eric Simning, Paul Winters.

p. cm. — (IDB Working Paper Series ; 519)

Includes bibliographical references.

1. Land titles—Paraguay. 2. Land tenure—Paraguay. 3. Land use—Paraguay. 4. Agriculture—Paraguay. I. Corral, Leonardo. II. Simning, Eric. III. Winters, Paul. IV. Inter-American Development Bank. Office of Strategic Planning and Development Effectiveness. V. Title. VI. Series.

IDB-WP-519

<http://www.iadb.org>

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Land Accumulation Dynamics in Developing Country Agriculture*

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Abstract

Understanding land accumulation dynamics is relevant for policy makers interested in the economic effects of land inequality in developing country agriculture. We thus explore and simultaneously test the leading theories of microlevel land accumulation dynamics using unique panel data from Paraguay. The results suggest that farm growth varies systematically with farm size – a formal rejection of stochastic growth theories (that is, Gibrat's Law) – and that titled land area may have considerable influence on land accumulation. Furthermore, our estimates indicate that a dualistic agrarian structure is the likely product of the unfettered operation of land markets.

Key words: Dynamic panel models; land accumulation; land inequality; Paraguay
JEL codes: C23; O13; O54; Q15

*The authors would like to thank Laura Schechter for providing the data for the project, Kevin Curran for assisting with data cleaning, and the Inter-American Development Bank (IDB) for financial support. Further, for their helpful comments we would like to thank participants of the IDB's 2012 workshop Evaluating the Impact of Tenure Security Interventions in Developing Countries as well as those of the 2013 Annual World Bank Conference on Land and Poverty. The views expressed here are those of the authors and should not be attributed to the IDB or its member countries.

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The distribution of agricultural landholdings in developing countries is a relatively well-documented source of economic inefficiency. Whether due to multiplier effects (Mellor 1976), credit rationing (Deininger and Squire 1998), or fostering extractive institutions (Acemoglu et al. 2002), inequality in the distribution of land has been linked to diminished economic growth. Such inequality has also been found to mitigate the poverty-reducing effects of existing growth, as asset-impooverished households commonly lack the capacity to make productive investments (Deininger and Squire 1998; Ravallion and Datt 2002; Lipton 2009). Furthermore, due to the often-observed productivity advantage of small-scale agricultural producers, it has been demonstrated that inegalitarian distributions of land have adverse effects on agricultural productivity (Eswaran and Kotwal 1986; Vollrath 2007; Lipton 2009).

While documentation of the consequences of inequality is prevalent, the causes are less well understood. Historically, in developing countries the allocation and reallocation of agricultural landholdings has been driven by inheritance and administrative processes (e.g. land reform) (Binswanger et al. 1995; Deininger and Feder 2001; Lipton 2009). The increasing prominence of land rental and sales markets, however, raises questions regarding the forces driving land accumulation (or decumulation) when private initiative is predominant (Boucher et al. 2005; Deininger and Jin 2008; Holden et al. 2009).¹ Theories of such land accumulation dynamics have invoked stochastic growth processes, factor market imperfections, or institutional/legal considerations, among others, in attempting to explain observed distributional outcomes. Yet, with few exceptions, such theories have not been subject to adequate empirical scrutiny.

Consider one of the most influential theories of firm (or farm) growth dynamics, which is known as “Gibrat’s Law of Proportionate Effects.” Gibrat’s Law posits that firm growth is a stochastic process, operating independently of firm size, and the limiting distribution of firm size is log-normal (Gibrat 1931; Sutton 1997). For the agricultural sector, Gibrat’s Law thus suggests that land accumulation is inherently stochastic. The theory has received considerable empirical attention in the context of developed country agriculture. For example, Jarrett (1968), Shapiro et al. (1987), Weiss (1999), and Melhim et al. (2009a) rejected Gibrat’s hypothesis for the cases of Australia, Canada, Austria, and the United States, respectively, whereas Clark et al. (1992) and Fulton et al. (1995) found support for the theory using data from Canada, and Melhim et al. (2009b) found similar support for the United States. Conversely, the only empirical analysis to date set within the context of developing country agriculture is Shergill (1991) who found support for Gibrat’s Law for the case of India. To the extent that developing countries have less well-defined property rights or even less well-functioning land and financial markets, we would expect the developed/developing distinction to be salient when testing Gibrat’s Law.

Regarding institutional/legal considerations, a more nuanced example can be found in the empirical literature exploring the economic effects of land tenure security. Since well-defined property rights are expected to mitigate expropriation risk, facilitate gains from trade, and support financial market transactions, it is theorized that tenure security promotes investment in and the efficient use of physical and human capital (Besley and Ghatak 2010). A number of studies have indeed found positive effects of land formalization on land-related investments (Feder et al. 1988; Besley 1995; Deininger and Ali 2008) and land market activity (Deininger et al. 2003; Boucher et al. 2005; Deininger and Jin 2008).² While these findings are suggestive of the fact that tenure security exerts influence on the distribution of agricultural landholdings, the link has yet to be conclusively examined and quantified. Boucher et al. (2005), for example, explored distributional outcomes before and after land market liberalization in Honduras and Nicaragua in the 1990s, but the land formalization effect was not uniquely identified as formalization initiatives were but one component of the reforms.³

In this context, we seek to further the literature examining the causes of inegalitarian distributions of agricultural landholdings in developing countries. We specifically examine the case of Paraguay, which represents a particularly appropriate setting due to the country’s history of land inequality and conflict as well as the scope of its liberalization efforts. With unique panel data for the years 1991, 1994, 1999, 2002, and 2007, we thus employ a generalized method of moments (GMM) estimator for dynamic panel models in an effort to simultaneously test the leading theories of micro-level land accumulation dynamics. The results of the analysis suggest that farm growth indeed varies systematically with select observable characteristics (i.e. land operated and titled area), which implies a formal rejection of Gibrat’s Law. Furthermore, the estimates suggest that a dualistic agrarian structure is the likely product of the unfettered operation of land markets, though land titling interventions may possess the capacity to reduce the rate at which inequality is manifested.

The rest of the article is organized as follows: “Theoretical Considerations” elaborates upon the leading theories of land accumulation dynamics, “Paraguay Background and Data” provides background on Paraguay as well as discusses the available data, “Methodology” outlines the methodological approach and empirical model, “Results” describes the results of the analysis, and “Conclusions” discusses conclusions and limitations of the analysis.

Theoretical Considerations

The leading theories of farm growth or land accumulation dynamics considered in this article are six-fold and are classified by the primary phenomenon invoked: (1) stochastic growth processes; (2) factor market imperfections; (3) institutional/legal considerations; (4) the life cycle hypothesis; (5) heterogeneous managerial experience; and (6) differential human capital. In what follows, we discuss each of these theories in turn, providing formal treatment where possible.

Beginning with stochastic growth processes, one of the earliest and most influential of such theories is the previously mentioned “Gibrat’s Law of Proportionate Effects.”⁴ Put forth by Robert Gibrat in his work *Inégalités Économiques* (1931), the theory attempts to explain the widespread appearance of skewed distributions, most notably with respect to firm or farm size. To illustrate Gibrat’s Law, let x_t denote firm size at time t and the random variable ε_t denote the proportional rate of growth such that $x_t = x_{t-1}(1+\varepsilon_t) = x_0(1+\varepsilon_1)(1+\varepsilon_2)\dots(1+\varepsilon_t)$ or $\log(x_t) \approx \log(x_0) + \varepsilon_1 + \varepsilon_2 + \dots + \varepsilon_t$. Under the assumption that ε is i.i.d. with mean μ and variance σ^2 , as $t \rightarrow \infty$ the distribution of $\log(x_t)$ is approximately normal with mean $t \cdot \mu$ and variance $t \cdot \sigma^2$. Gibrat thus contended that firm growth $g_t \equiv \log(x_t) - \log(x_{t-1}) \approx \varepsilon_t$ is a stochastic process and the limiting distribution of firm size is log-normal. Most importantly, the central testable hypothesis is that firm growth is independent of initial firm characteristics, most notably firm size (Sutton 1997).⁵

Regarding factor market imperfections, Carter and Mesbah (1993) developed a theory of land market competitiveness whereby a systematic relationship between farm growth and farm size manifests. On the basis of exogenously-given land endowments, utility-maximizing agents choose their optimal time allocation (i.e. on-farm and off-farm labor) and purchased inputs (i.e. hired labor and fertilizer usage) in the presence of labor and capital market imperfections.⁶ Let $\pi(T)$ be the optimal value function where T is the land endowment.⁷ The reservations price for ε additional hectares of land is then $\rho(T) = \sum_{t=1}^{\infty} \Delta_t(T) / [1 + \mu(T + \varepsilon)]^t$ where $\Delta_t(T) = [\pi(T + \varepsilon) - \pi(T)] / \varepsilon$ and $\mu(T + \varepsilon)$ is the shadow price of capital. The authors found that the smallest farm units witness relatively high reservation prices due to their high marginal unemployment in the labor market. That is, the relatively high valuation of land follows from their low opportunity cost of labor. Medium-sized farms also demonstrated high reservation prices due to their ability to overcome labor and capital market imperfections. That is, the relatively high valuation of land follows from their simultaneous ability to access credit and avoid labor supervision issues. Therefore, as reservation prices are expected to be highly correlated with farm growth rates, it is contended that farm size is an important determinant of farm growth or land accumulation, though the relationship may be highly non-linear with the smallest and medium-sized farms most likely to accumulate.⁸

With respect to institutional/legal considerations, Carter and Olinto (1998) incorporated notions of tenure insecurity into a land market competitiveness model similar to that described above. Letting $0 < \phi < 1$ denote the single-period probability that a given household is dispossessed of its land, the reservation price of land becomes $\rho(T) = \sum_{t=1}^{\infty} [(1-\phi)^t \Delta_t(T, \phi)] / [1 + \mu(T + \varepsilon, \phi)]^t$. Tenure insecurity affects the reservation price formulation through three distinct channels: (1) the term $(1-\phi)^t$ introduces uncertainty-based discounting of future earnings; (2) the presence of ϕ in $\Delta_t(\cdot)$ suggests that tenure insecurity may depress incremental earnings from land by affecting factor allocations; and (3) the incorporation of ϕ in $\mu(\cdot)$ reflects the fact that tenure insecurity may have credit supply effects due to the collateralizability of land. Thus, all else equal, the theory hypothesizes that tenure insecurity reduces incentives to accumulate land as $\partial\rho/\partial\phi < 0$. There may, however, be important interaction effects between tenure insecurity and land endowments as the lesser-endowed tend to be excluded from credit markets regardless of the legal collateralizability of their land (Carter 1988).

Turning to the life cycle hypothesis, Chayanov (1966) was among the first to suggest that land accumulation is intimately tied to the growth of the individual family. Stated simply, assuming the absence of a well-functioning labor market, Chayanov suggested that farm size passively adapts to the equilibrium level of income of a given agricultural household, which is determined by balancing the marginal utility of income and the marginal drudgery of labor. The location and shape of these curves was said to be heavily influenced by family size and composition, as the marginal utility of income depends upon family consumption demands and the marginal drudgery of labor hinges upon the size of the family work force. In traversing the family life cycle,⁹ the family initially witnesses increasing consumption demands due to the augmentation of family size, which induces a steady upward shift in the marginal utility of income curve. However, as the children become of working age, there then appears a downward shifting of the marginal drudgery of labor curve due to the reduced degree of labor intensity per worker. The interaction of these forces, then, generates a persistently increasing equilibrium level of income and, thus, farm size (Harrison 1975; Banaji 1976).

Another alternative theory focuses on the relationship between managerial experience and firm growth, and is based upon the learning model put forth in Jovanovic (1982). In the model, at time t , firms choose their output level q_t so as to maximize expected profits $p_t q_t - c(q_t) x_t^*$ where p_t is the exogenously-given output price, $c(q_t)$ is the cost function, and x_t^* denotes the expectation of x_t , which is a random variable capturing efficiency considerations. For a firm of type θ , $x_t = \xi(\eta_t)$ where $\xi(\cdot)$ is a positive, strictly increasing, and continuous function, and $\eta_t = \theta + \varepsilon_t$ where $\varepsilon_t \sim N(0, \sigma^2)$. While θ is unknown for a given firm, the distribution of θ across firms is known. Further, η_t can be inferred by observing costs at time t . Letting n

be the age of a given firm and $\bar{\eta}_n = \sum_{i=1}^n \eta_i/n$, we can then write $x_t^* = \int \xi(\eta) P^0(\cdot | \bar{\eta}_n, n)$ where $P^0(\cdot | \bar{\eta}_n, n)$ is the normal posterior distribution of η_t , the variance of which only depends on n . It is thus clear that x_t^* converges to a constant as firms age, which implies an equilibrium scale of production for mature firms. While younger firms have more variability in growth rates, it can also be shown that they will grow faster, as Jovanovic demonstrated that growth is an increasing function of x_t^*/x_{t+1}^* and $E(x_t^*/x_{t+1}^*) > 1$. It is hypothesized then that there exists an inverse relationship between firm growth and firm age.

Finally, the effects of human capital on land accumulation can be understood in terms of the structural evolution model put forth in Rodgers (1994).¹⁰ Agents in the model have two human capital attributes, x and y , where x represents agriculture-specific human capital and y represents general human capital.¹¹ On the basis of such endowments, agents then choose whether to engage in agricultural production or off-farm employment. Off-farm income w is assumed to be an increasing function of general human capital (i.e. $\partial w/\partial y > 0$). Agricultural income m is determined by choosing land d and purchased inputs k to maximize profits $pxF(d, k) - rd - vk$ where p is the price of agricultural output, $F(\cdot)$ is a standard production function, and the unit prices of d and k are r and v , respectively. Given that the marginal products of d and k are increasing functions of x , agents with relatively high x will choose to farm as $m > w$. Agents with relatively high y , however, will choose off-farm employment as $w > m$. It is then hypothesized that the equilibrium distribution of land is driven by the distribution of the two types of human capital across agents. More interestingly, agricultural producers with relatively high x likely grow faster as technology adoption costs may vary inversely with human capital levels.¹²

This collection of theories offers a series of hypotheses regarding land accumulation dynamics. Pure stochastic growth suggests that land accumulation is independent of producer-level characteristics and appropriately constructed hypothesis tests should yield no statistically significant results. Carter and Mesbah's (1993) model attributes patterns of land accumulation to labor and capital market imperfections, and posits a link between land endowments and farm growth. Institutional/legal considerations imply that tenure security may affect land accumulation while Chayanov's (1966) model highlights the importance of demographics, particularly the influence of household labor and dependents. Finally, the learning and structural evolution models focus on two related factors, experience and human capital, thereby suggesting a role for years working in agriculture and the education level of the producer. The objective of the analysis is then to identify whether and to what extent the stated factors influence farm growth, thus simultaneously testing the leading theories of land accumulation dynamics.

Paraguay Background and Data

Before discussing the methodological approach used to examine the alternative hypotheses considered in the previous section, the Paraguayan setting and available data are considered. As such, with special emphasis on the distribution of agricultural landholdings, this section first provides an overview of Paraguay's agricultural sector. After this contextual discussion, we then discuss the data collection process and descriptive statistics associated with the unique panel data set used in the empirical analysis.

Paraguay, with a gross domestic product per capita of \$2,967 and a poverty rate of 38 percent, is among the poorest countries in Latin America. Moreover, economic growth in Paraguay is intimately tied to the agricultural sector, as agriculture accounts for 24 percent of gross domestic product, 27 percent of the country's employment, and 87 percent of total merchandise exports (World Bank 2013).¹³ With an estimated land Gini coefficient of 0.93, the distribution of landholdings in Paraguay is one of the most inegalitarian in the world (Lipton 2009). On the one hand, just over 63 percent of producers operate landholdings less than ten hectares, but account for just over two percent of total farming area. On the other hand, under two percent of producers operate landholdings greater than 1,000 hectares and account for nearly 80 percent of total farm land. Compounding issues of land inequality is the existence of pervasive tenure insecurity, as approximately 27 percent of producers do not have rights over the land they operate. Moreover, of those producers operating less than five hectares, 36 percent are classified as illegal squatters (Ministerio de Agricultura y Ganadería 2012).

Unlike much of Latin America, the development of Paraguay's *latifundia-minifundia* system is not primarily rooted in 16th century European colonization.¹⁴ The concentration of landholdings and marginalization of the peasantry is instead largely grounded in the aftermath of the War of the Triple Alliance (1864-1870), whereby large tracts of state land were sold to foreign investors and Paraguayan elite as a means to settle war debt. In the 20th century, this dualistic agrarian structure was then exacerbated by population growth, a lack of opportunities outside of agriculture, and a system of partial inheritance that induced further *minifundia* fragmentation, most notably in Paraguay's central region (Baer and Birch 1984; Danielsen 2009). The Stroessner regime (1954-1989), viewing the resulting inegalitarian distribution of land as a source of productive inefficiency and rural unrest, thus enacted the Agrarian Statute of 1963 and embarked on a large-scale colonization program with the stated intent to increase rural welfare. In practice, however, land was primarily distributed to associates of the regime (e.g. armed forces, rural elite, government officials, etc.), which led to the replication of the *latifundia-minifundia* system in the colonization areas (Weisskoff 1992; Nagel 1999).

The fall of the Stroessner regime in 1989 created space for the expression of rural discontent, which was manifest primarily in a wave of land occupations. As such, in the ensuing democratization and liberalization process, issues of land inequality and tenure insecurity became firmly established on the national political agenda. As a reflection of the continued strength of the rural elite, however, the new constitution of 1992 excluded the traditional usufruct right to land, provided a strong guarantee to property rights, and generally left land redistribution to market forces (Nagel 1999; Danielsen 2009). With continued *campesino* unrest and renewed calls for agrarian legislation, the Agrarian Statute of 2002 was then enacted after a protracted period of political deadlock. The new legislation was nonetheless technical rather than redistributive in character, and the stated aim of rural development and poverty alleviation was to be achieved through increased productivity, the stimulation of agro-industry, and overall reduction of market interventions. Thus, legislation in the post-Stroessner era reflects the emergence of liberal democratic values and a shift toward neoliberal economic policies (Danielsen 2009).

Based on agricultural census data for the years 1956 to 2008, Table 1 provides information on the distribution of farms and landholdings by farm size categories. Looking at the data for 1956, it is evident that the Stroessner regime inherited considerable inequality as nearly 70 percent of producers operated farms less than ten hectares, but accounted for just over two percent of the total land cultivated. Conversely, in that same year, just over three percent of producers operated farms greater than 100 hectares, but accounted for nearly 93 percent of the total land cultivated. Largely due to the regime's land colonization programs, it is apparent that the number of farms and area cultivated expanded greatly by 1991. The inequalitarian distribution of landholdings, however, remained intact, as in that year the largest four percent of producers operated 88 percent of total land cultivated. Finally, the liberalization process that began after 1991 appears to have been accompanied by a further concentration of landholdings, as the percentage of land operated by producers with less than ten hectares decreased from approximately three to two percent whereas that operated by producers with more than 100 hectares increased from 88 to over 92 percent.

As gaining insight into the micro-level forces inducing distributional changes throughout the liberalization period is greatly facilitated by panel data, it is thus beneficial to turn to the discussion of the data used in the empirical analysis. In 1991, the Land Tenure Center (LTC) at the University of Wisconsin-Madison and the *Centro Paraguayo de Estudios Sociológicos* (CPES) administered surveys to 300 rural Paraguayan households, which were selected in accordance with a stratified, multi-stage random sampling framework. The sample was distributed across three regions of Paraguay: (1) the traditional "*minifundia*" zone located in the department of Paraguari, which is characterized by small plots and low soil fertility, but possesses a

favorable proximity to the country's largest cities; (2) the colonization zone in the department of San Pedro, which is characterized by higher quality soils, fewer land conflicts, but lacking infrastructure; and (3) the frontier region located in the department of Itapúa, which is characterized by the best land, the highest rainfall, and larger farms employing modern technology.¹⁵ Within these regions, the sample was further stratified by household land endowments (0-5, 5-10, 10-20, 20-50, and >50 hectares).

The LTC-CPES survey is panel in nature and was again administered in the years 1994, 1999, 2002, and 2007. For a variety of reasons, issues of attrition included, households were strategically added to the sample in select years. As such, the panel is unbalanced with 300, 284, 293, 223, and 446 reliable observations in the years 1991, 1994, 1999, 2002, and 2007, respectively. Importantly, 139 households were successfully surveyed in each of the five years, 70 were surveyed in four of the years, 41 in three of the years, 65 in two of the years, and the remaining households were only surveyed once. Because the sample continued to be stratified by land endowment, it is proportionally representative across land categories, though there are few farms greater than 50 hectares and thus limited observations in the largest farm size category. Further, while it is evident that the number of households interviewed in each survey year is relatively small, such shortcomings are partially compensated by the depth of the interviews administered. Particularly relevant at present are the detailed modules on modes of land access, property rights, household characteristics and individual-level demographic traits, as well as production and income. For further information regarding the LTC-CPES survey see Fletschner and Zepeda (2002), Carter and Olinto (2003), or Schechter (2007).

Table 2 provides definitions for all variables utilized in the analysis and Table 3 presents descriptive statistics. The variables defined follow directly from the discussion in "Theoretical Considerations."¹⁶ As the definitions and descriptive statistics are largely self-explanatory,¹⁷ we focus our attention on Figure 1, which offers an alternative perspective on changes in farm sizes across the survey period. Using the balanced sub-panel, we divided the sample in the baseline period into four mutually exclusive groups according to land operated (see legend for categorization scheme), and then plotted mean land operated for each cohort in each survey year. Three patterns are worth noting. First, the degree of variability in each series is particularly interesting, as it is suggestive of non-negligible land market activity and potentially interesting accumulation dynamics. Second, while the 5-10 hectare cohort seemingly stagnated throughout the survey period, the other groups witnessed episodes of considerable growth. The 10-20 hectare cohort, for example, witnessed an approximate doubling of mean farm size from 1999 to 2007. Finally, mean farm size of the <5 hectare cohort actually surpassed that of the 5-10 hectare cohort by 2002 and remained (slightly) greater in 2007, suggesting a degree of convergence across these smallest farm size categories.

Methodology

The previous section demonstrated that legislation in Paraguay’s post-Stroessner era created space for private initiative to stimulate change in the distribution of agricultural landholdings. It was further demonstrated that the era was characterized by non-negligible land market activity and potentially interesting accumulation dynamics. In light of these observations, this section considers the methodological approach and empirical model associated with our evaluation of the theories discussed in “Theoretical Considerations.”

While our specific empirical model is discussed in detail below, it is first instructive to consider, in a generalized context, estimation of the following autoregressive-distributed lag model:

$$(1) \quad y_{i,t} = \beta_1 y_{i,t-1} + \beta_2 x_{i,t} + \alpha_i + u_{i,t}$$

where, for producer $i = 1, 2, \dots, N$ at time $t = 1, 2, \dots, T$, $y_{i,t}$ denotes some firm size measure, $x_{i,t}$ is a vector of current or lagged values of additional explanatory variables, α_i is the producer-specific effect, and $u_{i,t}$ is the error term, which is assumed to be serially uncorrelated and independent across producers. Finally, β_1 and β_2 represent parameters to be estimated (Bond 2002).

Estimation of Eq. (1) via the within-groups estimator is inconsistent as the requisite transformation introduces a correlation between the transformed $y_{i,t-1}$ and the transformed error term. First-difference and orthogonal deviations transformations can also eliminate the individual effects α_i , but in both cases the correlation between the transformed $y_{i,t-1}$ and transformed error term persists.¹⁸ However, as opposed to the within-groups estimator, the first-difference and orthogonal deviations transformations do not introduce all realizations of the disturbances into the transformed equation, thereby implying that further lags of the explanatory variables are available to be used as instruments. For example, in the orthogonal deviations case, recalling that the disturbances are assumed to be serially uncorrelated and further assuming that initial conditions are predetermined,¹⁹ $y_{i,t-2}$ is uncorrelated with $u_{i,t}^\perp = c_t \left[u_{i,t} - \frac{1}{T-t} (u_{i,t+1} + \dots + u_{i,T}) \right]$,²⁰ and the 2SLS estimator is consistent in large N , fixed T panels (Anderson and Hsiao 1982; Arellano and Bover 1995; Bond 2002; Roodman 2009b).

While the 2SLS estimator is consistent, it is not asymptotically efficient since it does not utilize all available moment conditions or account for the transformed nature of the error term. Arellano and Bond (1991) developed a generalized method of moments (GMM) estimator for dynamic panel models in an effort to remedy the shortcomings of the 2SLS approach. The authors noted that, for $T > 3$, additional instruments are available as, for example, $y_{i,t-2}$ and $y_{i,t-3}$ can be used as instruments for the transformed equation when

$t = 4$. In the context of a simple autoregressive model (i.e. $\beta_2 = 0$), the instrument matrix can be written as follows:

$$(2) \quad Z_i = \begin{bmatrix} y_{i,1} & 0 & 0 & 0 & 0 & 0 & \cdots \\ 0 & y_{i,1} & y_{i,2} & 0 & 0 & 0 & \cdots \\ 0 & 0 & 0 & y_{i,1} & y_{i,2} & y_{i,3} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

or “collapsed” as

$$(3) \quad \begin{bmatrix} y_{i,1} & 0 & 0 & \cdots \\ y_{i,1} & y_{i,2} & 0 & \cdots \\ y_{i,1} & y_{i,2} & y_{i,3} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

where, for the i^{th} entity, the rows correspond to the transformed equation for periods $t = 3, 4, \dots, T$.²¹ The above is readily generalized to the case of the autoregressive-distributed lag model under consideration and the additional covariates may be endogenous, pre-determined, or strictly exogenous. While the availability of further instruments will depend on the assumptions made regarding the correlation between the additional explanatory variables and the error term, for illustrative purposes let $x_{i,t}$ be scalar and endogenous. Accordingly, the vector $(y_{i,1}, \dots, y_{i,t-2})$ can be replaced by $(y_{i,1}, \dots, y_{i,t-2}, x_{i,1}, \dots, x_{i,t-2})$ in forming each row of the instrument matrix.

Using orthogonal deviations as the choice transformation, the asymptotically efficient GMM estimator exploits the moment conditions $E[Z_i' u_i^\perp] = 0$ for $i = 1, 2, \dots, N$ where $u_i^\perp = (u_{i,3}^\perp, u_{i,4}^\perp, \dots, u_{i,T}^\perp)'$ to minimize the following criterion:

$$(4) \quad J_N = \left(\frac{1}{N} \sum_{i=1}^N u_i^{\perp'} Z_i \right) W_N \left(\frac{1}{N} \sum_{i=1}^N Z_i' u_i^\perp \right)$$

where

$$(5) \quad W_N = \left[\frac{1}{N} \sum_{i=1}^N (Z_i' \hat{u}_i^\perp \hat{u}_i^{\perp'} Z_i) \right]^{-1}$$

is the optimal weight matrix and \widehat{u}_i^\perp denotes estimates of the corresponding residuals, which are calculated from a preliminary consistent estimator. As such, the method is known as a two-step GMM estimator. The dependence of the two-step weight matrix on estimated parameters, however, makes the asymptotic distribution approximations unreliable, and thus standard errors are generally calculated using the finite-sample correction put forth in Windmeijer (2005) (Arellano and Bond 1991; Bond 2002; Roodman 2009b).

Blundell and Bond (1998), building on Arellano and Bover (1995), noted that when the series in question has near unit root properties, the utilized instruments are likely to be weak. In such situations it may be the case that past changes are more predictive of current levels than past levels are of current changes or deviations (Roodman 2009b). To fix ideas, reconsider the simple autoregressive case (i.e. $\beta_2=0$). Blundell and Bond suggested utilizing the additional $T-2$ linear moment conditions $E[\Delta y_{i,t-1}(\alpha_i + u_{i,t})]$ for $i = 1, 2, \dots, N$ and $t = 3, 4, \dots, T$ where $\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$.²² In exploiting the new moment conditions, the authors developed a “system” GMM estimator whereby the $T-2$ equations in orthogonal deviations (or first-differences) and the $T-2$ equations in levels are stacked and the instrument matrix is augmented as follows:

$$(6) \quad Z_i^+ = \begin{bmatrix} Z_i & 0 & 0 & 0 & \dots \\ 0 & \Delta y_{i,2} & 0 & 0 & \dots \\ 0 & 0 & \Delta y_{i,3} & 0 & \dots \\ 0 & 0 & 0 & \Delta y_{i,4} & \dots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

or “collapsed” as

$$(7) \quad \begin{bmatrix} Z_i & 0 \\ 0 & \Delta y_{i,2} \\ 0 & \Delta y_{i,3} \\ 0 & \Delta y_{i,4} \\ \vdots & \vdots \end{bmatrix}.$$

Estimation then consists of minimizing J_N after properly introducing the additional moment conditions. Further, analogous to the case of the Arellano and Bond GMM estimator, Z_i^+ readily incorporates additional instruments associated with the autoregressive-distributed lag model.

Turning to the empirical model, in line with the above discussion as well as the firm growth literature (Evans 1987; Sleuwaegen and Goedhuys 2002; Rizov and Mathijs 2003; Dries and Swinnen 2004), the following basic specification is put forth:

$$(8) \quad \frac{\ln(y_{i,t}) - \ln(y_{i,t-1})}{\delta_t} \times 100 = \ln [g(y_{i,t-1}, x_{i,t-1})] + \alpha_i + u_{i,t}$$

where, for producer $i = 1, 2, \dots, N$ at time $t = 1, 2, \dots, T$, $y_{i,t}$ represents land operated and δ_t is the number of years between survey periods t and $t - 1$. The left-hand side is thus an approximation of the annual percentage growth rate in land operated. Regarding the right-hand side, $x_{i,t-1} = (x_{1,i,t-1}, \dots, x_{5,i,t-1})$ is a vector of lagged values of pre-determined variables including titled area, labor, dependents, experience, and education, respectively,²³ α_i is the producer-specific effect, and $u_{i,t}$ is the error term. Approximating the growth function $g(\cdot)$ by a second-order expansion in the logs (i.e. utilizing a series of quadratic and interaction terms) and augmenting the basic model with time dummies results in the empirical model to be estimated.²⁴

Eq. (8) nests tests of all hypotheses discussed in “Theoretical Considerations.” First, joint independence of initial producer characteristics from subsequent land accumulation would provide support for Gibrat’s Law. Second, appropriate signs and joint statistical significance of the coefficients capturing the (non-linear) effect of land operated on land accumulation would substantiate the hypothesis put forth by Carter and Mesbah (1993). Third, a positive and statistically significant coefficient on titled area would corroborate the contention of Carter and Olinto (1998) that tenure security incentivizes land accumulation. Fourth, a positive and statistically significant coefficient on labor (dependents) would lend support to the life cycle hypothesis that land accumulation is induced via shifting downward (upward) the marginal drudgery of labor (marginal utility of income) curve. Fifth, a negative and statistically significant coefficient on experience would substantiate the hypothesis of Jovanovic (1982) that younger farms grow faster. Sixth, as Rodgers (1994) suggested that both agricultural-specific and general human capital are influenced by formal education, the effect of education on land accumulation is *a priori* ambiguous.²⁵ Finally, it is important to note that although some of these factors may be significant, lack of explanatory power may suggest that Gibrat’s Law largely holds conditional on a few key covariates.

Note that Eq. (8) is simply a special case of the autoregressive-distributed lag model previously discussed. As such, utilizing orthogonal deviations to minimize data loss due to the unbalanced nature of the panel, we employ the Arellano and Bover (1995)/Blundell and Bond (1998) “system” GMM estimator outlined

above. With the exception of the time dummies which are deemed exogenous, all explanatory variables are treated as predetermined. The appropriateness of the specification rests primarily on the validity of four assumptions: (1) the disturbances lack serial correlation; (2) the instruments are exogenous; (3) the instrument count is sufficiently small; and (4) attrition bias is absent or minimal. The first three of these assumptions are examined post-estimation. We explore the serial independence assumption with the Arellano and Bond (1991) test for first-order serial correlation in the disturbances and the instrumental exogeneity assumption with Hansen (1982) tests for overidentifying restrictions. Further, as too many instruments can bias parameter estimates and weaken the Hansen test (Roodman 2009a), we monitor the instrument count throughout and examine the sensitivity of the results to reductions.

Regarding issues of attrition, “growth rates can only be measured for surviving farms (i.e. those still operating in period t), and since slow growing farms are most like to exit the industry, it is easy to see that small, fast growing farms can easily be overrepresented in the sample, thus introducing potential bias in the results” (Bakucs and Fertő 2009, pg. 790). While the vast majority of the empirical literature to date suggests that the resulting bias is negligible (Evans 1987; Hall 1987; Weiss 1999; Dries et al. 2004), to gain further insight into this problem we conducted two types of tests for attrition bias: (1) the Beckett et al. (1988) attrition test and (2) the Fitzgerald et al. (1998) attrition probit. As it is the primary variable of interest, each test was conducted with three alternative specifications of land operated (i.e. in levels, logarithms, and growth rates), yielding a total of six tests. In only one such test do we reject the null hypothesis of no attrition bias at the five percent level, thereby suggesting that the issue of attrition is likely minimal.²⁶ Accordingly, we avoid undue complication of the estimation procedure and focus on surviving farms.

Results

Tables 4 and 5 present the results from the Arellano and Bover (1995)/Blundell and Bond (1998) “system” GMM estimator. Given that instrument proliferation is a primary concern, we estimate three alternative models in order to examine the sensitivity of the results to reductions in the instrument count: (1) FM, which is the full model using the instrument set defined in Eq. (6); (2) CM, which is the collapsed model using the instrument set defined in Eq. (7); and CR, which is the collapsed model where the instrument set is further restricted to only two-period lags. Each model is estimated with a full set of time and “zero value” dummies (see footnote 24). Note also that the number of instruments utilized, the associated R^2 values, and

the number of observations are provided for each regression at the bottom of the corresponding column in Table 4.

Looking at Table 4, as testament to the consistency of the of the “system” GMM estimator, we can exploit the fact that OLS and within-groups estimates of the coefficient on the (natural log of the) lagged land operated variable (y) are biased in opposite directions. That is, the OLS estimator is biased upward and the within-groups estimator is biased downward (Bond 2002). OLS estimation of the model yields a coefficient on the lagged land operated variable of -51.42 and within-groups yields a coefficient of -64.70 .²⁷ In each of our three models the coefficient on the lagged land operated variable falls within this range, which suggests that the “system” GMM estimates indeed represent an overall improvement. Given reasonable estimates, then, we can proceed to an in-depth examination of the validity of the underlying assumptions as well as probe the implications of our estimates for the hypotheses in question. To this end, Table 5 presents a series of related hypothesis tests.

Hypothesis tests (1)-(3) in Table 5 present the results from the specification tests discussed in the previous section. Hypothesis test (1) displays z -scores from the Arellano and Bond (1991) test for first-order serial correlation in the disturbances. Hypothesis test (2) displays test statistics from the Hansen (1982) test for overidentifying restrictions. Hypothesis test (3) presents a difference-in-Hansen test statistic, which tests the validity of the instrument subset associated with the levels model (i.e. the differenced instruments introduced in Eq. [6]). Looking at the FM column, we fail to reject the null hypothesis of no serial correlation for hypothesis test (1), and instrumental exogeneity for hypothesis tests (2) and (3). At first glance the specification thus appears appropriate. However, as mentioned, instrument proliferation can greatly weaken the Hansen tests, and both Hansen tests here are associated with an extreme p -value of 1.00, which suggests that the instrument count is excessively high. Proceeding with caution, then, we turn to hypothesis tests (4)-(9) where we present estimates of the marginal effect of (the natural log of) each regressor, which are evaluated at the sample means.

The results show that the marginal effects on dependents (x_3), experience (x_4), and education (x_5) witness no statistical significance, which suggests that land accumulation seemingly operates independently of these covariates. Of those marginal effects that witness statistical significance (i.e. y , x_1 , and x_2 or land operated, titled area, and labor, respectively), it appears that all signs are in broad accordance with the theoretical notions discussed in “Theoretical Considerations.” With respect to land operated, the associated marginal effect indicates that, at the mean, a one percent increase in the quantity of land operated is expected to induce a statistically significant 0.15 (i.e. $14.86/100$) unit decrease in the annual percentage growth rate of

operational landholdings. This finding implies a formal rejection of Gibrat’s Law and is consistent with the contention of Carter and Mesbah (1993) that smaller farms witness relatively high land reservation prices. Further, it is evident that the positive marginal effects associated with titled area and labor, which can be interpreted analogously, corroborate the associated theories: an increase in land titled and household labor tend to induce land accumulation.²⁸ While these results indicate a formal rejection of Gibrat’s Law, note that the R^2 of the model is 0.10 suggesting that much of farm growth remains unexplained.

Due to the relatively high instrument count in the FM model (275), these estimates are potentially suspect. As such, the CM regression utilizes the collapsed instrument set, which serves to reduce the instrument count to 128. Looking to the CM column of Table 5, we see that we again fail to reject the null hypotheses for tests (1)-(3). With p -values of 0.63 and 0.28 for Hansen tests (2) and (3), respectively, it is possible to proceed with less concern regarding issues of instrument proliferation. Regarding hypothesis tests (4)-(9) in the CM column, then, it is evident that the marginal effects associated with x_3 , x_4 , and x_5 remain insignificant. Further, while the marginal effect on titled area (x_1) remains positive and statistically significant, the marginal effects associated with land operated (y) and labor (x_2) are now statistically insignificant. Further yet, we see that the magnitude of the marginal effect on titled area is reduced to 10.62 from 14.83 in the FM regression. These results show that the estimates are moderately sensitive to the instrument count. As such, it is beneficial to consider reducing the number of instruments further.

The CR regression, as mentioned, utilizes the collapsed instrument set and additionally restricts lags to two periods. This serves to further reduce the instrument count to 97. Once again, in no case do we reject the null hypothesis for tests (1)-(3) in the CR column in Table 5. Furthermore, with p -values of 0.64 and 0.73 for Hansen tests (2) and (3), respectively, it appears possible to take yet greater comfort in the instrument set employed. With respect to the hypothesis tests on the marginal effects, then, we see that the effects associated with x_2 through x_5 remain statistically insignificant. Moreover, the marginal effect associated with titled area (x_1) remains statistically significant and of a similar magnitude to the CM regression. The primary difference between the CM and CR regressions is that the marginal effect on land operated (y) is now statistically significant, though the magnitude of the effect is similar. Given that the CR regression is our preferred specification and that both land operated and titled area witness statistical significance, examining further the economic implications of the associated coefficients is beneficial.

Figure 2 depicts the relationship between the annual percentage growth rate in operational landholdings and initial land operated. The figure was constructed by retrieving the predicted values from the CR regression model and then regressing those predicted values on initial land operated using a fractional

polynomial regression (Royston and Altman 1994). Interestingly, the figure implies three distinct growth regimes. Those farms operating less than approximately 5.5 hectares tend toward positive growth rates until reaching an equilibrium size of 5.5 hectares where growth is equal to zero. Those farms operating between approximately 5.5 and 350 hectares tend toward negative growth rates until arriving at that same equilibrium of 5.5 hectares. Finally, those farms operating greater than approximately 350 hectares appear to persistently grow.²⁹ Most importantly, however, the figure conforms surprisingly well to the predictions of the model put forth by Carter and Mesbah (1993), as the authors contended that a dualistic agrarian structure is the likely product of the unfettered operation of the land market.

Table 5 also illustrates that titled area exerts influence on land accumulation. Accordingly, Figure 3 depicts the relationship between the annual percentage growth rate in operational landholdings and initial land operated after a hypothetical land titling intervention. The *ex ante* curve is identical to that plotted in Figure 2 and is provided for purposes of comparison. The *ex post* curve was constructed analogously, but with one simple change: the predicted values from the CR regression were calculated after substituting the quantity of land owned for titled area. This change reflects a situation in which a hypothetical property rights intervention provides formal title to all land owned by the surveyed households. Interestingly, the accumulation barriers remain identical to those of Figure 2 (i.e. 5.5 and 350 hectares). The hypothetical intervention, however, appears to have reduced the rate at which the 5.5-350 (>350) hectare regime decumulates (accumulates) operational landholdings. While a tendency toward dualism persists, property rights reform may thus possess the capacity to reduce the rate at which inequality manifests itself. Overall, then, the results associated with titled area conform reasonably well to the theoretical model put forth in Carter and Olinto (1998).

Conclusions

To the extent that (1) inequalitarian distributions of agricultural landholdings in developing countries are a perceived source of economic inefficiency, and (2) land rental and sales markets are the primary mechanism by which agricultural land is allocated and reallocated, an improved understanding of land accumulation dynamics is of considerable policy interest. While theories of such accumulation dynamics are relatively numerous, empirical scrutiny of the associated hypotheses is relatively scarce. With unique panel data from Paraguay, in this article we employ a generalized method of moments (GMM) estimator for dynamic panel models in an effort to simultaneously test the leading theories. The signs associated with the statistically

significant effects empirically substantiated two of the hypotheses put forth: (1) that initial land operated is an important determinant of land accumulation (Carter and Mesbah 1993) and (2) that titled area may exert a non-negligible influence on farm growth (Carter and Olinto 1998). As land accumulation was thus found to vary systematically with select observable characteristics (i.e. land operated and titled area), we formally rejected the theory of stochastic growth (i.e. Gibrat's Law).

Interestingly, the estimates suggested that a dualistic agrarian structure is the likely product of the unfettered operation of land markets, though land titling interventions may possess the capacity to reduce the rate at which inequality manifests. A thorough examination of the latter finding is beyond the scope of the present analysis. However, we speculate that, as tenure insecurity is often posited to relate inversely with producer wealth and/or income, land titling interventions may disproportionately benefit small- and medium-sized agricultural producers. An important caveat to this statement is that credit markets tend to persistently exclude asset-impooverished households regardless of the legal collateralizability of their land (Carter 1988), a consideration consistent with the finding that the smallest producers were little affected by our hypothetical property rights reform. Thus, while land titling interventions may reduce the rate at which inequality manifests, it is possible that additional benefits could be realized if such interventions were accompanied by policies to improve the functioning of credit markets.

Finally, although we consider our analysis to be an important advance in the understanding of land inequality in developing countries, it is beneficial to recognize its limitations. First, for reasons of data availability and institutional context, we focused exclusively on the case of Paraguay. Second, even though the panel data utilized was unique in its length, the number of producers in each cross section was relatively small. Third, while great care was taken to illustrate that attrition bias is likely an issue of negligible importance, we avoided undue complication of the estimation procedure and focused on surviving farms. Future research may thus consider exploring similar research questions in other countries/settings, particularly with emphasis on wider panel data sets and adjustments for issues of attrition.

Notes

¹It is important here to clarify our use of the term “accumulation.” We define land accumulation as “the acquisition or gradual gathering of land use rights or land access for purposes of agricultural production.” Notably, this includes expansion of the farm unit via legal (e.g. ownership, rental, or sharecropping arrangements) or extralegal (e.g. squatting) means. As opposed to the term farm growth, land accumulation appears less ambiguous as farm growth can occur along multiple dimensions (e.g. growth in the quantity or value of output, capital accumulation, employment increases, etc.). We do, however, use the terms land accumulation and farm growth synonymously throughout.

²It is important to note that such positive effects are by no means a universal finding. Several studies have found that land-related investment (Migot-Adholla et al. 1991; Gavian and Fafchamps 1996; Brasselle et al. 2002) and land market activity (Deininger and Jin 2005; Gould 2006; Barnes and Griffith-Charles 2007) are not appreciably affected by land formalization.

³The reforms, for example, included measures to remove government from all forms of direct land redistribution, to end prohibitions on land rental and sale, and to activate private credit markets.

⁴See Champernowne (1953), Reed (2001, 2003), or Reed and Jorgensen (2004) for other notable stochastic growth theories.

⁵In the wake of *Inégalités Économiques*, a wealth of empirical literature has emerged seeking to test Gibrat’s Law, much of which has focused on the agricultural sector and farm size growth. Such empirical tests typically consist of estimating some variant of the following: $\ln(x_{i,t}) - \ln(x_{i,t-1}) = \alpha + \beta \ln(x_{i,t-1}) + u_{i,t}$ where $x_{i,t}$ represents the size of farm i at time t , α and β are parameters to be estimated, and $u_{i,t}$ is the error term. Rejection of the null hypothesis $\beta = 0$ entails a rejection of Gibrat’s Law (Weiss 1999).

⁶More specifically, labor market imperfections entail that hired labor requires supervision and agents who seek off-farm employment face a distinct probability of unemployment. Credit market imperfections entail that the quantity of working capital available to a given agent depends on that agent’s land endowment.

⁷For the sake of brevity, all other arguments in $\pi(\cdot)$ are suppressed.

⁸In other words, “the model identifies an agrarian structure composed of mid-sized farms, and poverty refuge *minifundias* as a likely outcome of the unfettered operation of the land market” (Carter and Mesbah 1993, pg. 1097).

⁹The life cycle was said to begin with the marriage of the nuclear couple, then proceed through child-bearing and rearing, the entrance of the children into the family work force, and finally end with the exit of the children from the household to form families of their own.

¹⁰See Sumner and Leiby (1987) for an alternative, albeit similar, theoretical model.

¹¹Agriculture-specific human capital x is assumed to be primarily determined by learning-by-doing, though formal education may also play an important role. General human capital y is assumed to be determined by formal education, employment history, and inherent ability.

¹²Rodgers also suggested that agricultural producers with relatively high x may also grow faster due to the fact that they are able to spread fixed technology adoption costs over a greater quantity of output.

¹³The data presented above pertains to the year 2008.

¹⁴The *latifundia-minifundia* system is a dualistic agrarian structure composed of *latifundias*, or large hacienda-type estates or landholdings, and *minifundias*, which are small subsistence-oriented farms.

¹⁵These regions were selected primarily because they are precisely those regions where much of the country’s agricultural production and land scarcity problems are concentrated.

¹⁶See “Methodology” for a detailed discussion of the relationship of each variable to the hypotheses put forth in “Theoretical Considerations.”

¹⁷It is worth noting that in Table 3 the means of land operated and titled area are of a noticeably lower magnitude for 2007. This is primarily due to the addition of new units in 2007, though to some extent the differential persists even after omitting these observations.

¹⁸In contrast to the first-difference transformation in which a lagged observation is subtracted from the contemporaneous observation, the orthogonal deviations transformation subtracts the average of all future available observations. The primary benefit of using orthogonal deviations over differencing is that data loss is minimized in unbalanced panels (Arellano and Bover 1995).

¹⁹That is, $y_{i,1}$ is uncorrelated with subsequent disturbances $u_{i,t}$ for $t = 2, 3, \dots, T$.

²⁰In the orthogonal deviations expression, $c_t = \sqrt{(T-t)/(T-t+1)}$ is introduced to equalize the variances.

²¹The primary rationale for collapsing the instrument matrix is to reduce the instrument count. The class of models considered here tend to generate instruments prolifically, which can overfit endogenous variables and weaken select specification tests. See Roodman (2009a) for more information.

²²It is assumed here that changes in the instrumenting variables are uncorrelated with the fixed effects.

²³See Table 2 for variable definitions. Note also that the pre-determined nature of the additional explanatory variables is a testable assumption and we undertake tests for overidentifying restrictions to substantiate this claim (discussed below).

²⁴In situations where scaling is necessary to permit logarithmic transformation of zero-valued explanatory variables, we employ the dummy variable procedure outlined in Battese (1997), as alternative approaches (e.g. adding an arbitrarily small constant) can bias parameter estimates. The method is simple: recode all zero values of explanatory variables to one and include in the regression a corresponding dummy variable that takes on the value of one if that observation was recoded and zero otherwise. Note that dummy variables for land operated and experience are not necessary as these variables never take on a value of zero.

²⁵Data limitations preclude distinguishing between agricultural-specific and general human capital.

²⁶The results of the tests are available upon request.

²⁷Full OLS and within-groups results are available upon request.

²⁸The non-linear effects associated with these theories is further explored below. It is, however, worth mentioning that we attempted to include higher-order polynomials in the model, but their insignificance gave way to the more parsimonious specification presented.

²⁹While the estimates indeed imply continual growth among the latter regime, the number of observations in this regime is relatively few and more information may reveal a new equilibrium at the high end of the farm size spectrum.

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Appendix

Table 1: Distribution of Farms and Land by Farm Size

| | 1956 | 1981 | 1991 | 2008 |
|------------------------|------------|------------|------------|------------|
| Distribution of farms: | | | | |
| 0-5 ha | 45.9 | 36.0 | 40.0 | 40.5 |
| 5-10 ha | 23.4 | 19.9 | 21.7 | 22.9 |
| 10-100 ha | 27.4 | 40.0 | 34.3 | 30.2 |
| 100-500 ha | 1.9 | 2.8 | 2.7 | 3.6 |
| 500-1,000 ha | 0.4 | 0.4 | 0.5 | 0.9 |
| 1,000-10,000 ha | 0.8 | 0.8 | 0.9 | 1.4 |
| > 10,000 ha | 0.2 | 0.1 | 0.1 | 0.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Number of farms | 149,614 | 248,930 | 307,221 | 289,649 |
| Distribution of land: | | | | |
| 0-5 ha | 1.0 | 0.7 | 1.0 | 0.8 |
| 5-10 ha | 1.4 | 1.5 | 1.8 | 1.3 |
| 10-100 ha | 5.0 | 9.5 | 9.1 | 5.7 |
| 100-500 ha | 92.6 | 6.3 | 6.8 | 7.4 |
| 500-1,000 ha | | 3.2 | 4.2 | 5.8 |
| 1,000-10,000 ha | | 27.0 | 36.2 | 38.3 |
| > 10,000 ha | | 51.6 | 40.8 | 40.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Land cultivated | 16,816,618 | 21,940,531 | 23,817,737 | 31,086,894 |

Note: Data for the years 1956-1991 is from Danielsen (2009) and data for the year 2008 is from Ministerio de Agricultura y Ganadería (2012).

Table 2: Variable Definitions

| Variable | Definition |
|-----------------------|---|
| Land Operated (y) | Land owned plus land rented, sharecropped, or borrowed <i>from</i> others less land rented, sharecropped, or borrowed <i>to</i> others (hectares) |
| Titled Area (x_1) | Quantity of land owned with legally registered, mortgageable property rights (hectares) |
| Labor (x_2) | Number of household members ages 15 to 64 |
| Dependents (x_3) | Number of household members younger than 15 or older than 64 years of age |
| Experience (x_4) | Age of the household head less years of education of the household head less six years |
| Education (x_5) | Years of education of the household head |

Table 3: Descriptive Statistics

| Variable | 1991 | | 1994 | | 1999 | | 2002 | | 2007 | |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Land Operated | 32.16 | 72.30 | 38.29 | 86.87 | 34.82 | 83.33 | 38.24 | 99.63 | 19.87 | 61.90 |
| Titled Area | 21.09 | 64.75 | 29.48 | 85.10 | 21.84 | 62.30 | 30.49 | 91.93 | 11.05 | 42.71 |
| Labor | 2.93 | 1.55 | 2.61 | 1.35 | 2.88 | 1.73 | 3.22 | 1.64 | 2.88 | 1.54 |
| Dependents | 2.85 | 2.08 | 2.45 | 2.01 | 2.40 | 1.94 | 2.35 | 1.67 | 2.03 | 1.64 |
| Experience | 39.35 | 15.56 | 41.59 | 15.87 | 43.09 | 14.66 | 45.50 | 15.08 | 42.88 | 15.77 |
| Education | 4.13 | 2.74 | 4.12 | 2.72 | 4.27 | 2.48 | 4.56 | 2.65 | 4.73 | 2.86 |
| <i>N</i> | 300 | | 284 | | 293 | | 223 | | 446 | |

Note: The variables experience and education have only 291 observations for the year 1991. In the analysis, however, we utilize all 300 observations for the other variables.

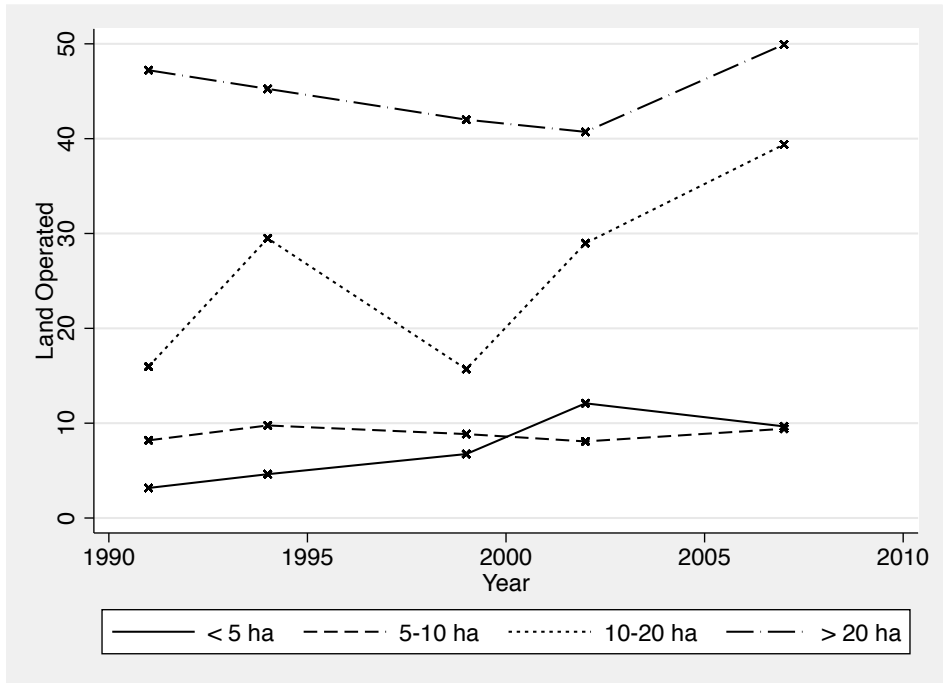


Figure 1: Mean farm size by cohort and year

Table 4: System GMM Estimates

| Variable | FM | | CM | | CR | |
|--------------------------|----------|-------|---------|-------|----------|-------|
| | Coeff. | SE | Coeff. | SE | Coeff. | SE |
| $\ln y$ | -53.88* | 27.72 | -52.77* | 29.94 | -62.75** | 30.54 |
| $\ln x_1$ | -2.09 | 19.56 | 8.92 | 17.89 | 16.98 | 20.02 |
| $\ln x_2$ | 49.87 | 38.49 | 20.66 | 28.08 | 19.36 | 33.50 |
| $\ln x_3$ | -1.20 | 31.38 | -13.61 | 36.41 | -11.28 | 40.23 |
| $\ln x_4$ | 74.84 | 67.78 | -19.33 | 80.33 | 25.32 | 94.10 |
| $\ln x_5$ | 76.21 | 46.92 | 22.81 | 54.62 | 41.03 | 58.32 |
| $(\ln y)^2$ | 3.51** | 1.49 | 3.58 | 2.33 | 3.31* | 1.75 |
| $\ln y \times \ln x_1$ | -5.97*** | 1.62 | -3.89** | 1.69 | -4.07** | 2.03 |
| $\ln y \times \ln x_2$ | 0.54 | 3.42 | 0.95 | 3.89 | 1.03 | 3.31 |
| $\ln y \times \ln x_3$ | 1.32 | 3.28 | 0.86 | 3.31 | 1.16 | 3.30 |
| $\ln y \times \ln x_4$ | 8.17 | 5.73 | 7.59 | 5.87 | 9.68* | 5.81 |
| $\ln y \times \ln x_5$ | 0.55 | 3.52 | -0.20 | 3.73 | 2.22 | 4.01 |
| $(\ln x_1)^2$ | 5.67*** | 1.68 | 2.65 | 2.10 | 2.50 | 2.11 |
| $\ln x_1 \times \ln x_2$ | 0.61 | 2.15 | -0.79 | 2.48 | -0.77 | 2.20 |
| $\ln x_1 \times \ln x_3$ | 0.40 | 2.05 | -1.11 | 1.96 | -0.99 | 1.74 |
| $\ln x_1 \times \ln x_4$ | 0.63 | 4.15 | 0.23 | 4.26 | -1.50 | 4.30 |
| $\ln x_1 \times \ln x_5$ | -0.36 | 2.43 | -0.11 | 3.30 | -0.38 | 3.68 |
| $(\ln x_2)^2$ | 2.96 | 3.46 | 3.42 | 3.72 | 2.25 | 3.58 |
| $\ln x_2 \times \ln x_3$ | -1.61 | 3.57 | -2.01 | 3.72 | -0.81 | 3.74 |
| $\ln x_2 \times \ln x_4$ | -11.87 | 9.02 | -4.03 | 6.18 | -3.21 | 7.09 |
| $\ln x_2 \times \ln x_5$ | -5.45 | 4.42 | -5.19 | 3.73 | -6.07 | 4.75 |
| $(\ln x_3)^2$ | 1.57 | 3.19 | 1.84 | 4.57 | 1.78 | 4.00 |
| $\ln x_3 \times \ln x_4$ | 0.92 | 7.01 | 5.16 | 8.09 | 3.81 | 9.12 |
| $\ln x_3 \times \ln x_5$ | -4.69 | 3.79 | -3.26 | 4.53 | -2.44 | 4.62 |
| $(\ln x_4)^2$ | -8.44 | 8.22 | 0.68 | 8.96 | -4.17 | 11.02 |
| $\ln x_4 \times \ln x_5$ | -17.50 | 11.12 | -1.47 | 12.60 | -8.83 | 13.63 |
| $(\ln x_5)^2$ | -0.72 | 4.10 | -3.82 | 6.61 | -0.74 | 6.38 |
| Fixed Effects | Yes | | Yes | | Yes | |
| Time Dummies | Yes | | Yes | | Yes | |
| Zero Value Dummies | Yes | | Yes | | Yes | |
| Instrument Count | 275 | | 128 | | 97 | |
| R^2 | 0.10 | | 0.10 | | 0.11 | |
| N | 820 | | 820 | | 820 | |

Note: P-values <0.01, 0.05, and 0.10 correspond to ***, **, and *, respectively. The subscripts 1, 2, 3, 4, and 5 refer to titled area, labor, dependents, experience, and education, respectively. Standard errors are calculated using the Windmeijer (2005) correction.

Table 5: Hypothesis Tests

| Hypothesis Test | FM | CM | CR |
|---------------------------------|-----------|---------|---------|
| (1) Arellano-Bond | 1.10 | 0.93 | 1.05 |
| (2) Hansen | 171.10 | 87.99 | 57.42 |
| (3) Difference-in-Hansen | 19.07 | 35.12 | 25.82 |
| (4) $\partial/\partial \ln y$ | -14.86*** | -10.16 | -10.74* |
| (5) $\partial/\partial \ln x_1$ | 14.83*** | 10.62** | 10.43** |
| (6) $\partial/\partial \ln x_2$ | 5.91* | 4.25 | 3.62 |
| (7) $\partial/\partial \ln x_3$ | 2.10 | 1.54 | 2.60 |
| (8) $\partial/\partial \ln x_4$ | 3.92 | 10.61 | 9.64 |
| (9) $\partial/\partial \ln x_5$ | -0.58 | -3.38 | 3.66 |

Note: P-values <0.01, 0.05, and 0.10 correspond to ***, **, and *, respectively. The subscripts 1, 2, 3, 4, and 5 refer to titled area, labor, dependents, experience, and education, respectively. Marginal effects are calculated at sample means.

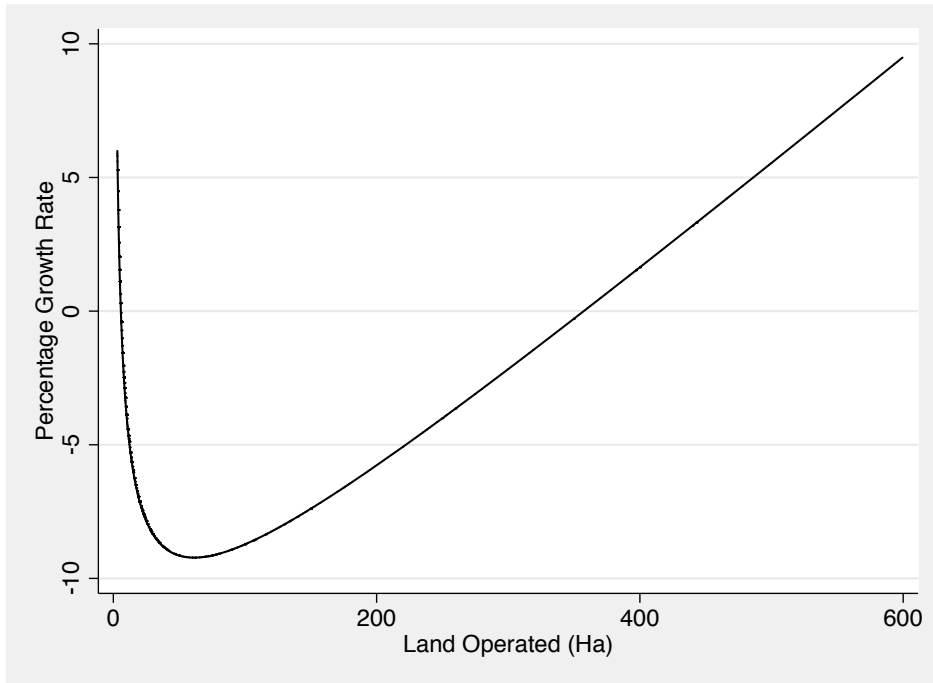


Figure 2: Predicted growth and land operated

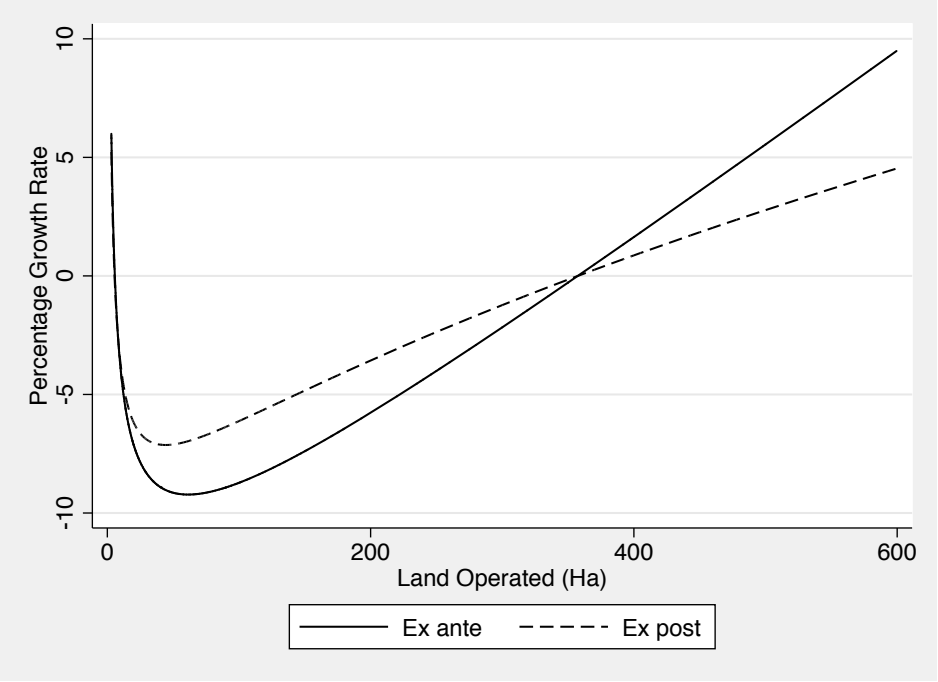


Figure 3: Predicted growth pre- and post-reform