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The Size Distribution of Farms and International Productivity Differences

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Abstract

There are striking differences in the size distribution of farms between rich and poor countries. We study the determinants of farm-size across countries and their impact on agricultural and aggregate productivity by developing a quantitative model of agriculture and non-agriculture that features a non-degenerate size distribution of farms. We find that differences in measured aggregate factors such as capital, land, and economy-wide productivity account for 1/4 of the observed differences in farm size and productivity. Farm-level policies that misallocate resources from large and productive farms to small and less productive farms are prevalent in poor countries and have the potential to account for the remaining differences. We assess the quantitative importance of misallocation in two ways. First, we construct a summary measure of farm-size distortions across countries by exploiting within-country variation in crop-specific price distortions and their correlation with crop farm size. This measure and aggregate factors jointly account for more than 1/2 of the cross-country differences in size and productivity. Second, we quantify the effects of specific policies in developing countries: a land reform that imposes a ceiling on farm size and a progressive land tax. We find that each individual policy generates a reduction of 3 to 7% in size and productivity.

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1 Introduction

Agriculture plays a key role in understanding the large disparities in aggregate labor productivity across countries. This is because poor countries are much more unproductive in agriculture than in non-agriculture when compared to rich countries and, at the same time, allocate a larger fraction of employment to agricultural activities than rich countries. Ever since T. W. Schultz (1953), the prominent explanation for the allocation of employment in agriculture in poor countries has been low productivity in that sector in the presence of subsistence requirements for food. The key question is then, why is measured labor productivity in farming so low in poor countries? A substantial literature has emerged addressing the productivity problem in agriculture in poor countries. While the literature has provided many useful insights and a better understanding of the productivity gap in agriculture, a large unexplained gap still remains.[1]

We show that farm size is an important factor in unraveling the low productivity problem in agriculture in poor countries. There are two observations that motivate our inquire into farm size:

(a) There are striking differences in the size distribution of farms between rich and poor countries with the operational scale of farms being considerably smaller in poor countries. Using internationally-comparable data from the World Census of Agriculture, we show that in the poorest 20% of countries the average farm size is 1.6 hectares (Ha), while in the richest 20% of countries the average farm size is 54.1 Ha, a 34-fold difference. In poor countries very small farms (less than 2 Ha) account for over 70% of total farms, whereas in rich countries they account for only 15%. In poor countries there are virtually no farms over 20 Ha, while in rich countries these account for 40% of the total number of farms.[2]

(b) Larger farms have much higher labor productivity (value added per worker) than smaller farms, implying that farm size differences can potentially have large effects on measured

[1]See for instance Kuznets (1971), Gollin, Parente, and Rogerson (2002), Caselli (2005), Restuccia, Yang, and Zhu (2008), Chanda and Dalgaard (2008), Vollrath (2009), Adamopoulos (2011), Lagakos and Waugh (2013), Gollin, Lagakos, and Waugh (2011), Herrendorf and Schoellman (2011), among others.

[2]See Grigg (1966) for an early documentation of differences in farm size across countries and Eastwood, Lipton, and Newell (2010) for more recent observations and historical trends.

agricultural productivity. Using data from the U.S. Census of Agriculture we document a 16-fold difference in value added per worker between the largest and smallest scale of operation of farms reported. Available data from other sources, based on national censuses and farm surveys, indicate that labor productivity rises with size in a large set of developing countries as well (see for instance Berry and Cline, 1979; Cornia, 1985). This occurs despite differences in land scarcity, soil, geography, agrarian structure, and form of agriculture observed among these countries.[3] In India, Foster and Rosenzweig (2011) show that efficiency rises with farm size.

We investigate why farm size differs across countries and we assess quantitatively the effect of farm-size differences on agricultural and aggregate productivity across countries. To guide our investigation, we develop a simple two-sector model of agriculture and non-agriculture that features a non-degenerate distribution of farm sizes. Our theory endogenizes farm size by embedding a Lucas (1978) span-of-control model of farm size in agriculture into a standard two-sector model. The novelty of the model lies in that agricultural goods are not produced by a representative farm but instead by farmers who are heterogeneous with respect to their ability in managing a farm. A farm is a decreasing returns to scale technology that requires the inputs of managerial skills of a farm operator and land and capital under the farmer's control. The optimal scale of operation of a farm is determined by the managerial ability of the farmer. Then, for a given distribution of managerial abilities, the model implies a distribution of farm sizes. There is a representative stand-in household that has preferences over agricultural and non-agricultural goods but faces a subsistence constraint for consumption of agricultural goods. The allocation of labor across sectors is driven by the interaction of the subsistence constraint with agricultural productivity.

We calibrate a benchmark economy to U.S. farm-level and aggregate observations. In particular, we approximate the distribution of farm-level productivity (farmer ability) by a log-normal distribution

[3]We note that rising labor productivity by size is not at odds with the stylized fact about the inverse relationship between land productivity (yields) and farm size. In the current and past U.S. Census of Agriculture, labor productivity increases with farm size at the same time that land productivity falls with size. These patterns are also observed in a wide range of developing countries and time periods (see for instance, Berry and Cline, 1979, and Cornia, 1985).

and choose its shape parameters to match the distribution of farm sizes in the U.S. Census of Agriculture. The model fits very well the farm-level data. In our theory, for a given distribution of farm-level productivity, higher economy-wide total factor productivity (TFP), capital, or land, results in larger farm sizes since fewer farmers are needed in agriculture to produce food. To evaluate the importance of aggregate factors on farm size and productivity, we measure in the data disparities between rich and poor countries in economy-wide productivity, the capital-output ratio, and land per capita. We find that the aggregate factors taken together cannot account for more than 1/4 of the differences in average farm size and agricultural productivity across rich and poor countries. What accounts for the large unexplained gap?

We focus on farm-level policies that misallocate resources across farms of different sizes, as a potential explanation in generating low farm size and low productivity in poor countries. There is ample evidence on a wide variety of institutions, frictions, and farm-level policies that distort size in poor countries suggesting that "smallness" is at least partly a symptom of misallocation within agriculture. The policies and institutions that directly or indirectly distort size in poor countries are usually "pro-small." For instance, many countries have implemented land reforms by setting an explicit ceiling for land holdings and breaking-up farms in excess of the ceiling (e.g., Bangladesh, Chile, Ethiopia, India, Korea, Pakistan, Peru, Philippines). Other countries distort size by imposing maximum and minimum size constraints (e.g., Indonesia and Zimbabwe). Several countries such as Zimbabwe, Pakistan, Brazil, and Namibia have imposed progressive land taxes, where larger farms are taxed at a higher rate than small farms. Ethiopia had a steep progressive agricultural income tax schedule for farmers. Several African countries (e.g. Kenya, Malawi, Tanzania, Zambia) have provided input subsidies only to smallholders. In India, tenancy reforms provided tenure security and preferential right of purchase to tenants which could also hinder farm growth. Bridgman, Maio, Schmitz, and Texeira (2012) show how production quotas (that disproportionately hurt large estates) and maximum farm size restrictions negatively affected the sugar-cane industry in Puerto Rico. We provide a detailed documentation of some farm-size distortions in developing countries in Appendix D. We note that, besides the policies we document, many other general type institutions such as imperfect land markets and credit constraints can also manifest themselves as farm-size distortions.

To get a quantitative handle on the importance of misallocation induced by farm-size distortions, we calibrate idiosyncratic producer-level taxes in poor countries to match differences in average farm size between rich and poor countries. We find that the model with aggregate factors and producer-level taxes can account for the entire rich-poor gaps in the sectoral share of employment and productivity. Are there empirically observable size-dependent taxes that can generate a quantitatively large drop in both farm size and productivity?

A key component of our analysis is that we provide a quantitative assessment of the importance of misallocation in agriculture using observable policy measures. We do this in two ways. First, we construct a summary measure of farm-size distortions across countries using internationally comparable data on agricultural distortions from the World Bank (see Anderson and Valenzuela, 2008). In particular, we use product-specific price distortions, measured as gaps between the farm-gate price and the international price for each product, after controlling for transportation and distribution costs. The price gaps capture government induced policy distortions such as domestic taxes/subsidies, trade taxes, interventions in the domestic foreign exchange market. A positive gap implies a subsidy for the producer of that product and a negative gap a tax. As is well known, poor countries typically tax agriculture. To obtain a summary measure of farm-size distortions we exploit the within-country variation in crop-specific taxes and correlate this variation with typical operational farm size for each crop. We find that in poor countries taxes tend to be higher on crops that are produced on a larger scale. Combining our empirical measure of farm-size distortions with aggregate factors, the model can account for over 1/2 of the differences in average farm size and agricultural productivity across rich and poor countries. This is a sizeable effect in the context of both the agriculture and the misallocation literatures. We find that the key quantitative effect on productivity is generated through misallocation that depresses average labor productivity in each size category (rather than reallocation across categories with productivities as in the benchmark economy).

Second, we assess the quantitative importance of specific policies that distort size by focusing on the institutional detail of particular developing country applications. We examine a land reform that caps farm size at a legislated ceiling. The specific policy we study is the 1988 Comprehensive Agrarian Reform Program (CARP) in the Philippines, which imposed a ceiling of 5 Ha on land holdings, redistributing the land in excess of the ceiling. In the model, the land reform in the Philippines reduces average size and agricultural productivity by 7%. While the drop in agricultural productivity is consistent with that observed in the Phillipines immediately after the reform, we show that to account for the data over a longer horizon, changes in aggregate factors have to be taken into account. As a result, increases in economy-wide TFP or capital accumulation can mask the negative productivity effects of the reform in time series data. Another widespread policy we examine is a progressive land tax. Specifically, we study the 1976 Amendment to the West Pakistan Land Revenue Act, which substituted a uniform land tax with a progressive tax by eliminating the land tax for farms under 5 Ha while increasing the tax on medium and large farms by 50%-100%. We find that the tax reform in Pakistan reduces size and productivity by 3%, and similar to the land reform, changes in aggregate factors can mask these effects over time.

Our paper is related to a growing macroeconomics literature that studies quantitatively the role of agriculture in understanding international income differences such as Gollin, Parente and Rogerson (2002, 2004, 2007), Caselli (2005), Restuccia, Yang and Zhu (2008), Chanda and Dalgaard (2008), Vollrath (2009), Adamopoulos (2011), Gollin, Lagakos, and Waugh (2011), Herrendorf and Schoellman (2011), and Lagakos and Waugh (2013).[4] Another important and growing literature emphasizes misallocation of resources across heterogeneous production units in generating aggregate and industry productivity effects such as Restuccia and Rogerson (2008), Guner, Ventura, and

[4]A broader related literature studies the sources and effects of the process of structural transformation that accompanies development: Echevarria (1997), Kongsamut, Rebelo, and Xie (2001), Caselli and Coleman (2001), Ngai and Pissarides (2007), Acemoglu and Guerrieri (2008), Duarte and Restuccia (2010), and Buera and Kaboski (2012a). Buera and Kaboski (2012b) emphasize the movement to large scale production units in manufacturing and services and their role in the structural transformation.

Xu (2008), Hsieh and Klenow (2009), among many others. We differ from these two broad literatures in emphasizing the size distribution of production units (farms) for the agricultural sector. More importantly, we use an empirically observable measure of farm-level distortions and assess its quantitative effect on both size and productivity. In addition, we quantify the effects of specific observable policies that generate misallocation.

We recognize that important differences in size across countries are also observed in other sectors of the economy. We focus on agriculture because this is a stark example of a sector where the observed differences in size distributions and labor productivity by size indicate a potential for large productivity effects. Further, productivity effects in the agricultural sector can translate into large differences in aggregate productivity between rich and poor countries as emphasized in Restuccia, Yang, and Zhu (2008), Caselli (2005), and the related literature. In addition, the particular farm-level policies we study are land policies, and hence specific to agriculture where land is an important factor of production.[5]

The paper proceeds as follows. Section 2 documents facts pertaining to farm size across countries and productivity differences across farms. In Section 3 we describe the model. Section 4 presents the calibration of the benchmark economy to U.S. data. In Section 5 we perform the cross-country quantitative experiments in terms of aggregate factors and farm-size distortions. Section 6 examines the quantitative effects of specific farm size distortions such as land reforms and progressive land taxes. We conclude in Section 7.

[5]The emphasis in this paper is on the productivity implications of the operational-scale distribution of farms and as a result we abstract from the welfare implications of ownership distribution policies and political economy considerations. See for example Engerman and Sokoloff (2000), Easterly (2001), Adamopoulos (2008), and Galor, Moav, and Vollrath (2009).

2 Facts on Farm Size

We document observations about farm size across countries using internationally comparable data from the *Report on the 1990 World Census of Agriculture* of the Food and Agricultural Organization (FAO) of the United Nations. The World Census of Agriculture collects data on the number of agricultural holdings and land area in holdings classified by size in hectares (Ha) for a large number of countries spanning the world income distribution. The World Census of Agriculture defines an agricultural holding as an economic unit of agricultural production under single management regardless of title, legal form, or size and may consist of one or more parcels. We refer to an agricultural holding throughout the paper as a farm. We combine these data with aggregate productivity data from the Penn World Table (PWT6.2) and agricultural productivity, employment, and land data from Rao (1993) to construct a data set of 63 countries in 1990. We rank countries according to real GDP per capita and allocate them into quintiles of the income distribution. A more detailed description of the data, variables used and countries is provided in Appendix A. We summarize our main findings with a special focus on the comparison of the richest and the poorest groups of countries. For these countries, the disparity in real GDP per capita is 21.1-fold, in real GDP per worker 19.2-fold, whereas the disparity in real agricultural GDP per worker is 46.7-fold.

2.1 Farm Size across Countries

Fact 1: Average farm size rises with the level of development. Figure 1 shows average farm size against real GDP per capita (in logarithms) across countries. Even though there are some outliers (such as Argentina and Australia) there is a systematic relationship between farm size and income, whereby richer countries tend to produce agricultural goods on a larger scale than poorer countries. Table 1 reports the mean of average farm size for each quintile of the income distribution. The average farm size in the poorest group of countries is 1.6 Ha whereas in the richest group is 54.1 Ha, a 34-fold difference. The median of average farm size rises smoothly with income across the income quintiles: 1.1, 2.6, 4.3, 14.2, 29.0 for each group. While land endowment, geographical location, land quality, and type of agriculture are relevant determinants of farm size across countries and there may be issues of measurement in farm size, the empirical literature has established a strong positive link between farm size and the level of development (see the surveys in Grigg, 1966; and Eastwood, Lipton, and Newell, 2010).[6] Indeed, in the context of the development process, it is natural that farm size increases with productivity as a productivity improvement generates a reallocation of labor out of agriculture. This implies that we would expect an increase in average farm size as countries grow over time, holding other factors constant. While farm size has in fact increased in developed countries over time, in several developing countries it has dropped substantially, implying divergence in average farm size between rich and poor countries (see for example Eastwood, Lipton, and Newell, 2010).

Table 1: Average Farm Size across Countries

Quintile	GDP per capita	Average Farm Size (Ha) Total	Wheat	Rice	Maize	Livestock Per Farm Cattle	Chicken	Sheep	Pigs
Q1	1,115	1.6	3.0	1.1	0.9	11.4	16.1	8.0	3.4
Q2	3,544	5.4	1.6	1.2	0.8	7.8	21.6	16.7	5.4
Q3	6,918	51.7	43.8	2.3	4.9	34.2	117.5	39.1	12.6
Q4	16,834	296.1	70.2	37.9	11.5	88.6	18275.3	449.9	184.3
Q5	23,562	54.1	27.9	41.3	33.0	52.6	4207.7	49.3	203.2

Source: GDP per capita is from PWT6.2. All other variables are from the World Census of Agriculture 1990.

The above differences in average farm size arise from systematic differences in the size distribution of farms between rich and poor countries. Figure 2 reports the percentage of farms that are small

[6] We find large differences in farm size even within narrowly defined crop (wheat, maize, rice) and livestock (cattle, chicken, sheep, pigs) categories between rich and poor countries although the exact magnitude differs by category (e.g., 39-fold difference in rice and maize and 9-fold difference for wheat), see Table 1. Also, while measures of geography may be correlated with farm size, the evidence is not always supportive of a strong link. For example in our sample, there is considerable variation in farm size within climate zones (e.g., tropics-subtropics vs. temperate, according to the Koeppen-Geiger climate zone classification, see Gallup, Sachs and Mellinger, 1999). There is also a weak correlation between average farm size and the mean distance to the nearest coastline or sea navigable river across countries.

(less than 5 Ha) and large (more than 20 Ha) across income groups. Richer countries have fewer small farms and more large farms than poorer countries. In the poorest countries (Q1) over 90% of farms are small and almost none of the farms are large, whereas in the richest countries (Q5) small farms account for about 30% of farms and large farms for nearly 40%. Histograms, for a finer breakdown of size categories, indicate that the share of farms is decreasing in size in poor countries, whereas the share of farms is increasing in size in rich countries. These facts suggest that small farms constitute the most common form of production unit in poor countries whereas large farms constitute the dominant production unit in rich countries. These patterns are even more striking if we focus on individual countries. For instance, for poor countries such as Ethiopia, Malawi, and Congo, more than 70% of farms are less than 1 Ha in size, whereas in rich countries such as Canada, United States, and United Kingdom, more than 70% of farms are more than 10 Ha in size. Another relevant feature of the data is that in poor countries, small farms account for a disproportionate share of land, whereas in rich countries large farms account for most of the land.[7] As we document in Figure 3, in the richest countries almost 70% of land is concentrated in large farms (more than 20 Ha), whereas in poor countries almost 70% of land is concentrated in small farms (less than 5 Ha).

2.2 Farm Productivity and Inputs by Size

The World Census does not report output or other inputs in addition to land by size. To gauge the potential importance of differences in productivity and inputs by farm size we look at farm-level data in the United States. Table 2 provides summary statistics from the 2007 U.S. Census of Agriculture.

Fact 2: Labor productivity (value added per worker) increases with farm size. In calculating value added per worker we take into account the relative hours worked by operators and hired labor. The factor difference between the largest and smallest scale of operation reported in the Census is

[7] This observation is reminiscent of what Lagakos (2009) reports for retail trade.

16-fold. This suggests that the difference in the allocation of farms across sizes between rich and poor countries alone could account for an important portion of the productivity gap in agriculture between these countries. In fact, a simple accounting exercise, where U.S. labor productivity by farm size is aggregated using the size distribution of farms in rich countries, reveals that aggregate agricultural labor productivity would fall by a factor of 4 if instead they had the poor country farm size distribution. We discuss the details of this counterfactual in Appendix A. However, while this observation represents a useful motivation for the importance of reallocation across farms in poor countries, we note that reallocation across heterogenous farms could generate productivity losses even in the absence of labor productivity differences across farms. To appreciate this point, notice that the baseline framework in the misallocation literature (e.g., Restuccia and Rogerson, 2008) is such that in the absence of distortions, factor demands equalize marginal products across production units, implying that labor productivity differences are also equalized. In this context, misallocation causes measured productivity losses to the extent that factors are reallocated across heterogeneous productive units as shown in that literature.

In Table 2 we also show that land productivity (value added per unit of land) decreases with farm size. The capital to land ratio also decreases with farm size. Large farms use more capital per farm than smaller ones, but they use much more land per farm so the capital to land ratio declines with size. These patterns are not unique to the United States. For example, Cornia (1985) reports data on 15 developing countries from Africa, Asia and Latin America for the 1970s where value added per worker tends to rise with farm size and both value added per unit of land and the capital to land ratio tend to fall with farm size.

The observations about the distribution of farm sizes across countries motivate our inquire of their importance in accounting for the large productivity gaps observed in agriculture between rich and poor countries.

Table 2: Statistics By Farm Size in the United States

Farm Size (Acres)	Farm Distribution	Land Share	Value Added Per Acre	Value Added Per Worker	Capital-Land Ratio
1-9	0.1056	0.0012	33.31	1.00	84.85
10-49	0.2813	0.0173	6.54	1.10	17.88
50-69	0.0698	0.0097	4.23	1.54	9.65
70-99	0.0871	0.0171	3.2	1.92	7.49
100-139	0.0794	0.022	2.67	2.22	5.96
140-179	0.0633	0.0238	2.4	2.67	4.98
180-219	0.0397	0.0187	2.59	3.38	4.73
220-259	0.031	0.0176	2.76	4.15	4.56
260-499	0.0964	0.0823	2.7	5.63	4.05
500-999	0.0679	0.1129	2.92	10.03	3.54
1,000-1,999	0.042	0.1384	2.52	14.25	2.95
2,000+	0.0365	0.5389	1.00	16.45	1.00

Source: Authors' calculations with data from the 2007 U.S. Census of Agriculture. Value added per acre and capital to land ratio are normalized relative to the maximum range values. Value added per worker is normalized relative to the minimum range value.

3 A Model of Farm Size

We consider a two-sector model of agriculture and non-agriculture featuring an endogenous distribution of farm sizes. In each period the economy produces two consumption goods: an agricultural good (a) and a non-agricultural good (n).

Technology The non-agricultural good is produced by a stand-in firm with access to a constant returns to scale technology that requires labor and capital as inputs,

$$Y_n = AK_n^{\alpha}N_n^{1-\alpha},$$

where Y_n is the total amount of non-agricultural output produced, K_n and N_n are the total amounts of capital and labor services employed in non-agriculture. A is an economy-wide productivity parameter (TFP), which is meant to capture institutions, policies, and distortions affecting the entire economy.

The production unit in the agricultural sector is a farm. A farm is a technology that requires the inputs of a farm operator with managerial skills s and land and capital under the farmer's control. The farm technology is characterized by decreasing returns to scale. Our specification of the farming technology is guided by the farm-level observations outlined in Section 2. In particular, a farmer of type s produces agricultural output according to a CES production function,

$$y_a = A\kappa \left[\theta k^\rho + (1-\theta)(s\ell)^\rho\right]^{\frac{\gamma}{\rho}},$$

where y_a is output of the farm, ℓ is the amount of land input, and k is the amount of capital.[8] There are three sources of productivity affecting the farming technology: (a) economy-wide productivity A which is common across sectors and all farms; (b) the sector-specific productivity term κ, that affects all units operating in the agricultural sector; and (c) the farmer's idiosyncratic productivity s. Our motivation for introducing farmer ability s as being land augmenting in a CES production function is to account for the observation that the capital to land ratios vary systematically with farm size. The parameter $\gamma \in (0,1)$ governs returns to scale at the farm level, often referred to as "span-of-control" parameter. The parameter $\theta \in (0,1)$ captures the relative importance of capital to land in the farming technology, and ρ determines the elasticity of substitution between capital and land $1/(1-\rho)$.

Preferences and Endowments The economy is endowed with fixed amounts of total farm land L and capital K. We abstract from capital accumulation in order to focus on the productivity effects resulting from the reallocation of resources across farms of different productivity. We consider an economy with a stand-in household that has preferences over the two goods according to the

[8]We abstract from hired labor in our analysis. The evidence suggests that hired labor as a share of agricultural labor does not vary systematically with the level of development across countries (see Chart 2.6 in Eastwood, Lipton, and Newell, 2010). Historical data for the United States reveals that the share of hired labor in total agricultural labor has remained remarkably stable at around 25% between 1910 and 1970, rising to about 35% since then (Historical Statistics of the U.S., Millennial Edition, Table Da612 -614). Further, while the inclusion of hired labor may be justified in other applications for which labor policies are important, the evidence suggests that land policies are at the core of farm-size differences across countries.

following per-period utility function

$$\phi \cdot \log(c_a - \bar{a}) + (1 - \phi) \cdot \log(c_n), \tag{1}$$

where $\bar{a} > 0$ is a subsistence constraint for agricultural consumption, and ϕ is a preference weight for the agricultural good. Consumption in each sector is denoted by c_i for $i \in \{a, n\}$. The household is composed of a unit-mass continuum of members.

Each household member is endowed with one unit of productive time that is supplied inelastically to the labor market. Whereas each household member is equally productive in the non-agricultural sector (with productivity normalized to one), household members are ex-post heterogeneous with respect to their productivity in the agricultural sector. Unlike in Lucas (1978), we abstract from selection in the occupational decision by assuming that the productivity of farmers in agriculture is realized after the sectoral allocation decision. The household decides what fraction of its members work in the agricultural sector, after which they draw their farmer managerial ability from a known time-invariant distribution with cdf $F(s)$ and pdf $f(s)$, with support in $S = [\underline{s}, \overline{s}]$. This assumption implies that the distribution of farmer's ability will be the same in all countries which precludes a potential selection channel into agriculture. The selection channel into agriculture has been studied in detail in Lagakos and Waugh (2013). Since this selection channel and other potential amplification mechanisms are well understood in the literature, we abstract from them in this paper in order to focus on the role of farm-level policies in generating misallocation and productivity gaps in agriculture in poor countries. The measure one assumption implies that we abstract from issues of risk sharing as the stand-in household acts under certainty with respect to the ability distribution.

Definition of Equilibrium We focus on a competitive equilibrium of the model. We assume that the stand-in household, firms in the non-agricultural sector, and farms in the agricultural sector behave competitively in factor and output markets. We assume the non-agricultural good is the numeraire, with its price normalized to one. The representative firm in non-agriculture takes the wage rate w and the rental price of capital r as given and chooses its demand for capital and labor services to maximize profits,

$$\max_{K_n,N_n}\{AK_n^{\alpha}N_n^{1-\alpha}-rK_n-wN_n\}. \tag{2}$$

A farmer with managerial ability s maximizes profits by demanding capital and land taking the rental prices of land and capital (q,r) and the relative price of the agricultural good p_a as given,

$$\max_{\ell,k}\pi(s)=\left\{p_aA\kappa\left[\theta k^{\rho}+(1-\theta)\left(s\ell\right)^{\rho}\right]^{\frac{\gamma}{\rho}}-q\ell-rk\right\}. \tag{3}$$

The stand-in household maximizes utility in (1) by choosing household consumption and the allocation of labor given prices subject to the following budget constraint:

$$p_a\cdot c_a+c_n=(1-N_a)w+N_a\int_S\pi\left(s\right)dF(s)+qL+rK\equiv I, \tag{4}$$

where I is the income of the household.

A *competitive equilibrium* is a set of allocations for: the household $\{c_a,c_n,N_a\}$, firm in the non-agricultural sector $\{K_n,N_n\}$, and farmers $\{[\ell(s),k(s),y_a(s)]_S\}$, and a set of prices $\{p_a,q,r,w\}$ such that: (*i*) given prices, the allocations of the household solve the household's problem (i.e., maximize utility in (1) subject to the budget constraint in (4)); (*ii*) given prices, the allocations of firms in non-agriculture and farmers in agriculture solve their problems in (2) and (3); and (*iii*) markets clear: for labor $N_a+N_n=1$; for capital $K_a+K_n=K$, where $K_a=N_a\int_S k(s)dF(s)$; for land, $L=N_a\int_S\ell(s)dF(s)$; and for agricultural and non-agricultural goods, $c_a=N_a\int_S y_a(s)dF(s)$ and $c_n=Y_n$.

The characterization of equilibrium is provided in Appendix B. Here we focus on the conditions that are less standard. The first order conditions for land and capital from the farmer maximization problem imply that the optimal capital-land ratio depends on the farmer ability s,

$$\frac{k}{\ell} = \left[\frac{\theta}{1-\theta}\frac{q}{r}\right]^{\frac{1}{1-\rho}} s^{-\frac{\rho}{1-\rho}}. \tag{5}$$

In order to generate the pattern that the capital-land ratio falls with farm size in the U.S. data, the theory would need $0 < \rho < 1$, which implies more substitutability between capital and land than Cobb-Douglas. The optimal scale of operation of a farm is determined by the managerial ability of the farmer. The optimality conditions imply that, other things equal, more able (higher s) farmers operate larger farms, demand more capital, produce more output, and have higher profits, as long as, $0 < \rho < \gamma < 1$. These parameter restrictions are satisfied in the U.S. data in the calibration of the model. Then, for a given distribution of managerial abilities the model implies a distribution of farm sizes.

The first order condition of the household with respect to the share of household members working in agriculture implies,

$$w = \int_S \pi(s)\, dF(s). \tag{6}$$

This no-arbitrage condition states that the household allocates its members across sectors until the return from non-agriculture is equal to the average profits in agriculture.

A Simplified Economy We illustrate the key properties of the model through a simple example whereby we abstract from capital in the economy, i.e., $\theta = \alpha = 0$. We also consider $\phi \to 0$ so that $c_a \to \bar{a}$. In this case, $\bar{a}$ is not only a subsistence term for food but also a satiation point and hence, the household only consumes $\bar{a}$ units of the agricultural good.[9] With these assumptions there is a closed-form solution of the model which implies that the total agricultural output in the economy is equal to $Y_a = A\kappa L^{\gamma}[E(s)N_a]^{1-\gamma}$ where $E(s) = \int_S s^{\gamma/1-\gamma} dF(s)$ is average ability. Since consumption of the agricultural good is equal to subsistence, $c_a = \bar{a}$, using the resource constraint in agriculture

[9]The optimality condition for agricultural consumption can be written as $c_a = \bar{a} + \phi p_a^{-1}(I - p_a\bar{a})$ where I is income of the household, which implies that as $\phi \to 0$, $c_a \to \bar{a}$. See Gollin, Parente, and Rogerson (2002) for preferences that deliver the same implication.

we can solve for the share of employment in agriculture,

$$N_a = \left[\frac{\bar{a}}{A \kappa L^{\gamma} E(s)^{1-\gamma}} \right]^{\frac{1}{1-\gamma}}.$$

The share of employment in agriculture is high when economy-wide productivity A is low, when agriculture-specific productivity κ is low, when the land endowment L is low, and when the efficiency of farmers $E(s)$ is low. By assumption in our model we abstract from potential differences in farmer's ability across countries. In our quantitative analysis we also maintain κ constant across economies. But misallocation of factors across farmers with different abilities operates through a reduction in measured productivity and acts in a similar fashion as a reduction in κ. Since average farm size is the ratio of land to employment in agriculture, the same objects that drive a high share of employment in agriculture also reduce the average farm size, with land endowment having both a direct and indirect effect on this statistic. As a result, average farm size differences are potentially driven by aggregate factors such as economy-wide productivity and land endowment as well as agriculture-specific distortions. Assessing the contribution of these factors in accounting for farm size and productivity differences across countries is the focus of our quantitative analysis in Section 5.

4 Calibration

We calibrate a benchmark economy to U.S. data. The parameters to be calibrated are: preference parameters $\{\overline{a}, \phi\}$, technological parameters $\{A, \kappa, \alpha, \theta, \gamma, \rho, \{s\}\}$, distributional parameters, and endowments $\{K, L\}$. While some of the model's parameters are shared with standard sectoral models, those pertaining to the farming technology and the distribution of farmer ability are new. Our calibration strategy involves choosing some parameters based on a-priori information and finding the rest as part of the solution of the model to match aggregate and farm-level targets in the benchmark economy.

We choose the distribution of farm-level productivity (farmer ability) to match the distribution of farm sizes in hectares for the U.S. economy from the 2007 U.S Census of Agriculture. Given that the distribution of farm sizes resembles a log-normal distribution, we assume a log-normal distribution for the distribution of farm-level productivity with mean μ and variance σ^2. We approximate the set of farmer productivities with a log-spaced grid of 6000 points in $[\underline{s}, \overline{s}]$, with $\underline{s}$ arbitrarily close to 0 and $\overline{s}$ equal to 100 which ensures farms of over 2,000 Ha. Our calibration involves a loop for the parameters of the productivity distribution: given values for (μ, σ), we construct a discrete approximation to a log-normal distribution of ability and solve the model matching the rest of the targets. The model then yields a distribution of farm sizes. We choose (μ, σ) to minimize the distance between the size distribution of farms in the model relative to the data. We normalize economy-wide productivity A and sector-specific agricultural productivity κ to 1 for the benchmark economy. We set the elasticity parameter in the non-agricultural technology $\alpha = 0.33$ to match the non-agricultural capital income share and $\gamma = 0.54$ to match the agricultural capital (including land) income share both at producer prices as reported in Table 1 of Valentinyi and Herrendorf (2008). Assuming a long-run share of employment in agriculture of 1% we set $\phi = 0.010$.

We choose parameters $(\overline{a}, \rho, \theta)$ to match three data targets: (1) a share of employment in agriculture of 2.5%, (2) an agricultural land income share of 18% (see Table 2 in Valentinyi and Herrendorf, 2008), and (3) a disparity in the capital to land ratio between the minimum and maximum farm sizes of 84.8. Note that the target on the capital to land ratio across farm sizes is informative for the elasticity of substitution between capital and land in the farming technology since in the model the capital to land ratio between any two farm sizes i and j is,

$$\frac{\left(\frac{k}{\ell}\right)_i}{\left(\frac{k}{\ell}\right)_j} = \left(\frac{s_i}{s_j}\right)^{-\frac{\rho}{1-\rho}},$$

so that a given distribution of abilities maps into differences in capital to land ratios depending on ρ. Since differences in capital to land drive differences in labor productivity (and yields) across farm sizes, this parameter may be important for our results. One concern with the target on capital to land ratios may be that the observed disparity across farms reflects a compositional bias due to: (a) large farms producing different agricultural goods (e.g., ranching) than small farms and (b) the set of goods in U.S. agriculture may not reflect the set of goods produced in poor countries. To address these issues, we calculate the capital-land ratio for selected agricultural goods (NAICS categories in the U.S. Census of Agriculture). These goods are representative of the production in the farm-size distribution in the United States and tend to be produced by both rich and poor countries: grains, vegetables, fruit, nuts, sheep, goats, pigs, eggs and poultry.[10] The average disparity between the minimum and maximum scale of operation over these categories is 83.6, which is very close to our target of 84.8 for the total average. The overall pattern is also similar for the average disparity between other size categories. The resulting calibrated parameter values are $\overline{a} = 0.035$, $\rho = 0.24$, and $\theta = 0.89$. We note that the calibrated value for ρ implies an elasticity of substitution between capital and land of 1.32 which is very close to Binswanger's (1974) estimate of 1.22 using U.S. state-level data. Given A and α, we choose the aggregate capital stock K to match a capital-output ratio for the U.S. economy of 2.5. We choose land to match an average farm size of 169.3 hectares for the U.S. economy. In our model average farm size is L/N_a, thus given the target $N_a = 0.025$, we choose $L = 4.2$ to match the average farm-size target.

Finally, we note that the value of labor productivity (value added per worker) in agriculture relative to non-agriculture in the benchmark economy is the inverse of the ratio of labor income shares, given by $(1-\alpha)/(1-\gamma)$. Our calibrated values for these parameters imply a ratio that is larger than one whereas it is well known that in the data for the United States it is around 0.5. The value productivity ratio is relevant for our analysis because it affects the units of agricultural labor productivity in the benchmark economy and, as a result, the units used to compute aggregate labor productivity across the experiments for distorted economies. In order to reconcile the value productivity ratio in the model with the data we introduce a barrier to labor mobility between agriculture and non-agriculture. In particular, we assume that working in non-agriculture is subject

[10] Note that these categories exclude ranching, feedlots, tobacco, cotton, sugarcane, among others, which may be conducive to more large-scale production and may not be produced by most poor nations.

to a tax $\xi \in (0, 1)$ such that the income of a worker in non-agriculture is a fraction of the commanding wage $(1-\xi)w$ which enters in the budget constraint of the household. We assume that tax revenues are wasted and thus the resource constraint of the non-agricultural good is affected. Specifically, total output in non-agriculture is used up by non-agricultural consumption and tax payments. We select the tax barrier ξ so that the value productivity ratio is 0.5. We further assume that ξ is constant across countries throughout our analysis.

The model parameters along with their targets and calibrated values are provided in Table 3. The calibrated model matches quite well several pertinent features of the U.S. agricultural sector. By choice of parameters of the distribution of ability, the model closely matches the size distribution of farms in the data. It also matches the capital to land ratios across farm sizes even though the calibration only targets the disparity between the largest and smallest size categories (see Figure 4). The model also matches well other statistics that were not objects of the calibration targets. For instance, the model generates a reasonable distribution of land across farm sizes by reproducing for example the observation that about 80% of the land is in farms over 20 Ha in size (see Figure 5, Panel A). The model is consistent with the positive relationship between farm size and labor productivity (value added per worker) observed in the data (see Figure 5, Panel B) as well as the well known inverse relationship between value added per hectare and size (see Figure 5, Panel C). These features make the model suitable for the quantitative analysis in the next section.

5 Quantitative Analysis

We use the calibrated model as a framework for understanding cross-country differences in the size of farms, the share of employment in agriculture, and agricultural and aggregate labor productivity. We focus on the differences between the richest and poorest countries.

Table 3: Parameterization

Parameter		Value	Target
Technology:	A	1	Normalization
	κ	1	Normalization
	α	0.33	Non-agricultural capital income share
	γ	0.54	Agricultural capital income share
	θ	0.89	Agricultural land income share
	ρ	0.24	Capital-land ratio between min-max sizes
Preferences:	$\overline{a}$	0.035	Current employment share in agriculture
	ϕ	0.010	Long-run employment share in agriculture
Ability Distribution:	μ	-1.83	Size distribution
	σ	4.66	Size distribution
Endowments:	K	3.9	Aggregate capital-output ratio
	L	4.2	Average farm size
Barrier:	ξ	0.66	Value productivity ratio

5.1 Aggregate Factors

We have shown that, in the context of our model, variations in aggregate factors affect the size and productivity of farms in the agricultural sector. In this section, we examine the quantitative effect of measurable aggregate factors such as land L, capital K, and economy-wide productivity A on average farm size and productivity. We first examine the effect of land differences since low land endowments are often cited as a source of small farm size in developing countries. We then examine the effect imparted by differences in all aggregate factors. The results of these experiments on the share of employment in agriculture (N_a), average farm size (AFS), agricultural labor productivity (Y_a/N_a), and aggregate labor productivity (Y/N) are reported in Table 4, along with statistics for the benchmark economy. We calculate real aggregate GDP measures across countries in the model using a common price for the agricultural good, in particular, we use the relative price of agriculture from the benchmark economy.[11]

[11]In practice the PWT uses international prices to construct aggregate measures of income across countries. Broadly speaking these prices are constructed as weighted averages of PPP-adjusted domestic prices across countries, however, the weights tend to render international prices that are close to those of rich countries. Nevertheless, we have verified that constructing aggregate labor productivity using the average price of agriculture from rich and poor countries renders nearly identical quantitative results.

Table 4: Effects of Aggregate Factors

	Benchmark Economy	+ Land Differences	+ (TFP, Capital) Differences	Data
Employment in Agriculture N_a (%)	2.5	2.6	16.6	65.3
Average Farm Size (AFS)	-	1.3	8.6	34
Labor Prod. in Agriculture (Y_a/N_a)	-	1	11.2	46.7
Aggregate Labor Productivity (Y/N)	-	1	7.6	19.2

Note: Average farm size, real labor productivity in agriculture and aggregate labor productivity are reported as the ratio between the benchmark economy and the poor economy. Land differences represent the difference in arable land per capita between rich and poor countries which is 1.3 fold. TFP and capital-to-output differences represent a factor of 2.5 and 2.9 between rich and poor countries.

We measure land endowments as arable land per capita in the data consistently with our model.[12] While richer countries have higher arable land per capita than poorer countries, this disparity is only 1.3-fold.[13] Not surprisingly then the model implies small disparities in the variables of interest across rich and poor economies. The share of employment in agriculture is roughly the same (2.6% rather than 2.5% in the benchmark economy). Given that in the model average farm size is L/N_a and N_a is close between the two economies, average farm size differs essentially by the disparity in the land endowment. Relative agricultural, non-agricultural, and aggregate productivities are virtually the same. We conclude that while differences in land endowments can potentially account for differences in size between rich and poor countries, this effect is quantitatively small, less than 4% of the observed differences in average size.

Next we ask whether differences in economy-wide productivity A and capital endowments K, in addition to land endowment differences can account for the disparities between rich and poor countries. In this experiment we vary economy-wide productivity A and capital K for the poor economy

[12]While we use the term "per capita," in mapping consistently the model to the data, we divide total arable land by the total number of workers in the economy rather than total population.

[13]We feed in the rich-poor disparity in land per capita to the benchmark economy. Given that land per capita differs not only between the United States and poor countries (2.96-fold), but also between the US and rich countries (2.20-fold), we repeat the experiment for each pair in turn, and then calculate the implied rich-poor ratio for each variable of interest. The results from this alternative approach are very similar to our approach of feeding in the rich-poor disparity in land directly.

so that the model matches a 6.8-fold disparity in non-agricultural productivity Y_n/N_n and a 2.9-fold disparity in the capital-output ratio K/Y as observed in the data. The model implies a share of employment in agriculture of 16.6% versus 2.5% in the benchmark economy. The poor economy experiences an 8.6-fold drop in average farm size and an 11.2-fold decline in agricultural labor productivity, well below the 34-fold disparity in average farm size and the 46.7-fold gap in agricultural productivity observed in the data between rich and poor countries. Hence, the model can account for about 1/4 of the differences in farm size and agricultural productivity observed in the data between rich and poor countries. This experiment also generates a 7.6-fold disparity in aggregate labor productivity. We note that aggregate factors can yield a large share of farms under 5 Ha (58.1% in the model versus 93.6% in the data) explaining the sizeable impact of aggregate factors on average farm size.

Another potentially important aggregate factor that can affect agricultural productivity is land quality. While a detailed analysis of the importance of land quality is beyond the scope of this paper, we summarize the evidence from the best available data on land quality and its potential impact on agricultural productivity, leaving the details of the description of the data and analysis to Appendix C. Traditional measures of land quality such as the percentage of agricultural land classified as arable or cropland, or the percentage of arable land or cropland that is irrigated are subject to the criticism that they can be affected by economic decisions and hence are not exogenous. However, new land quality measures have been constructed, such as those derived from the FAO's Global Agro-Ecological Zones (GAEZ, 2000) program, which are meant to capture exogenous differences in soil, terrain, and climate characteristics. Using these data and focusing on the best quality land within each country (i.e., the land that has no soil, terrain, or climate constraints) we find that the ratio of the average rich country to average poor in best quality land is 1.1.[14] Including additional classes of land (of moderate soil and terrain and moderate climate constraints) and using different weighting schemes we find a rich to poor ratio of suitable land per capita that ranges from 0.5 to

[14]This result does not imply that there are no important differences in land quality across countries, but rather that the differences are not systematically related to the level of development. For example, Norway is similar to Malawi (low end) in terms of unconstrained land per capita, while the U.S. is similar to Lesotho (high end).

1.6, again yielding relatively small differences. To assess the impact of these land quality differences on agricultural productivity, we use the empirical estimates in Wiebe, Soule, Narrod, and Brenman (2000). In the context of our model, we find that while aggregate factors without land quality generate a rich-poor disparity in agricultural productivity of 11.2, including land quality differences of 1.1, increases the rich to poor disparity in agricultural productivity to 11.7, an increase of less than 5 percent. If we consider the range of land quality differences from GAEZ discussed earlier, between 0.5 and 1.6, the disparity in agricultural productivity between rich and poor countries ranges from 9.9 to 12.5. This analysis suggests that while the effect of land quality is quantitatively non-trivial, it is unlikely to explain most of the remaining differences in agricultural productivity.

Rich Countries While aggregate factors alone cannot account for the bulk of the differences in agriculture between rich and poor countries, we note that aggregate factors explain the bulk of differences in size and productivity among developed countries, even for developed countries with large and small average farm sizes such as Canada and the Netherlands. Table 5 shows the results of the model with aggregate factors differences for all countries in the top quintile of the income distribution. While there are some country cases that require individual analysis such as Norway and Japan, the set of aggregate factors we consider in the model are capable of generating closely agricultural employment shares, average farm size and agricultural and aggregate labor productivity. As a summary, aggregate factors account on average for more than 60 percent of the farm size and productivity data for rich countries.

We conclude that while aggregate factors account for a large portion of the differences in size and productivity among rich countries, they only account for 1/4 of the differences between rich and poor countries. Hence, other factors that are specific to the agricultural sector must be affecting not only farm size but also agricultural productivity.

Table 5: Effects of Aggregate Factors in Rich Countries

	N_a(%)		AFS		Y_a/N_a		Y/N	
	Model	Data	Model	Data	Model	Data	Model	Data
Belgium	2.92	1.86	19.2	16.1	1.31	1.16	1.06	1.05
Netherlands	3.28	3.32	11.1	17	1.56	1.16	1.19	1.18
Germany	3.17	3.46	21.2	32.8	1.49	2.73	1.25	1.27
France	2.71	5.46	80.5	31.5	1.15	1.90	1.07	1.10
Japan	3.31	6.26	5.9	1.2	1.59	14.8	1.23	1.29
Canada	2.74	3.12	336	242	1.17	1.41	1.30	1.31
Denmark	3.17	4.6	77.7	37.8	1.49	1.49	1.36	1.37
Austria	2.81	5.93	42.9	26.4	1.23	2.89	1.08	1.11
Norway	2.79	5.26	41.1	10	1.21	4.74	1.09	1.13
Switzerland	2.74	3.85	12.3	11.8	1.17	2.73	1.02	1.04
Luxembourg	2.26	1.74	22.3	36.2	0.82	1.16	0.73	0.73
Rich (Q5)	2.77	3.93	61.9	42.1	1.19	1.88	1.09	1.11
Poor (Q1)	16.6	65.3	8.6	34	11.2	46.7	7.6	19.2

Note: N_a is the share of employment in agriculture, AFS is average farm size, and Y_a/N_a and Y/N are real labor productivity in agriculture and aggregate labor productivity reported as the ratio between the benchmark economy and each country.

5.2 Farm-Size Distortions

A possible explanation for the low agricultural productivity in poor countries is the presence of farm-size distortions that create misallocation of resources from large-productive farms to small less-productive farms. There is substantial evidence on farm-size distortions in developing countries. In some cases distortions in farm size may not be intentional, such as in the cases of inheritance norms favoring fragmentation (e.g. India), or high transport costs that force local small-scale farm production.[15] In addition, deep institutional problems in poor countries, such as land market imperfections (e.g., limited property rights and overlapping land claims), and credit constraints are also likely to operate as barriers to farm size growth and productivity. There are many cases however of farm-size distortions that are the result of deliberate policy measures. Furthermore, in recent

[15]See for instance Adamopoulos (2011) for a study on the role played by transportation frictions in misallocating resources across sectors.

times these policies typically exhibit a systematic pattern whereby larger farms are disadvantaged in favor of small farms, thus encouraging "smallness."[16] In Appendix D we provide a documentation of farm-size policies for several countries in Africa, Asia and the Americas.

Many countries have set direct restrictions on farm size. In most cases these restrictions were ceilings on the size of permitted land holdings and were imposed as part of post-war-period land reforms that redistributed land in excess of the ceiling (e.g., Bangladesh, Chile, Ethiopia, India, Korea, Pakistan, Peru, Philippines). In many cases the ceiling on land holdings were accompanied by prohibitions on selling and/or renting the redistributed land. Other countries have distorted size by also imposing minimum size requirements. This is done either directly by setting an explicit lower bound, as in the case of Indonesia and Puerto Rico or indirectly by setting conditions for subdivisions, such as a "viability assessment" in the case of Zimbabwe. Several countries have imposed progressive land taxes where larger farms are taxed at a higher rate than smaller farms (e.g., Brazil, Namibia, Pakistan, Zimbabwe). Several African countries have offered input subsidies for fertilizer and seed that are either directly targeted at smallholders or disproportionately benefited them (e.g., Kenya, Malawi, Tanzania, Zambia). In other cases smallholders were provided with subsidized credit (e.g., Kenya, Philippines) or grants to purchase land (e.g., Malawi). Tenancy regulations, such as rent ceilings, tenure security, preferential right of purchase (e.g., India), can also provide smallholders with an advantage.

But the fact that we can produce a long list of policies and institutions that affect the allocation of factors across heterogenous farmers does not immediately imply that these restrictions are quantitatively important in explaining low farm size and agricultural productivity in poor countries. To assess the quantitative importance of misallocation, we first follow the approach in Restuccia and Rogerson (2008), by introducing farm-size distortions in the model as generic output taxes on individual farmers, $\tau_s \geq 0$. We assume the government balances the budget by rebating tax

[16] Historically there have been land market interventions in several countries to establish and support large farms. For a documentation of such interventions see Ch.2 in Deininger (2003). In our framework policies favoring small or large farms are both distortionary.

receipts lump-sum to the stand-in household. Taxes are idiosyncratic to individual farmers and are meant to englobe the variety of policies and institutions affecting farm size. We implement these idiosyncratic taxes in the model by positing a generic tax function that specifies the output tax rate as a function of farmer's productivity as follows:

$$\tau_s = P(s) = 1 - \frac{1}{\exp(\psi s)},$$

where $P(\cdot)$ is the policy function, $\psi > 0$ is a parameter and s is the productivity of the farmer. For values of farmer's productivity greater than zero, the shape of this tax function is such that for low levels of farmer productivity the tax rate is very low and then increases approaching one for large values of farmer's productivity. The specific functional form of this tax schedule is motivated by the empirical evidence discussed earlier and further documented in Appendix D. Moreover, it summarizes in a parsimonious way the set of farm-level policies in developing countries that virtually exempt small farms from effective taxation, while imposing maximum taxes on large farms. The nearly 100% tax rates implied by the function for the very high ability farmers capture restrictions, taxes, and outright prohibitions, that effectively curtail production of large farms. The steep progressivity of tax rates implied by the function is also consistent with the evidence on actual taxes and other policies which change in a stark way across ranges of farm-size. We discipline the parameter ψ by selecting it to match the disparity in average farm size between rich and poor countries (34-fold) starting from an economy that features aggregate factors of poor countries. Hence, with this experiment we ask whether there is a tax schedule $P(s)$ that can generate sufficient misallocation as to reproduce the average farm size in poor relative to rich countries, and if so what its productivity implications are for poor countries.

The results of this experiment are in Table 6. Farm-size distortions, while chosen to match only differences in average farm size, reproduce other pertinent features of poor countries (compare columns 2 and 3 in Table 6). In particular, our model with aggregate factors and idiosyncratic taxes can entirely match the share of employment in agriculture in poor countries (65.2% in the model vs. 65.3% in the data) and agricultural and aggregate labor productivities (factor differences of 46.5 and 17 in the model vs. 46.7 and 19.2 in the data). In Appendix C we show that the results are robust to reasonable variations in the degree of substitutability between capital and land in the farm-level production function, with less substitution between capital and land actually amplifying the results of the model.

Before we move on to discuss the empirical discipline of the tax schedule, we discuss two implications. First, as is standard in the class of two sector models we build on, lower productivity of agricultural goods in poor countries translates into a higher relative price of agriculture. The relative price of agriculture in the model with generic farm-size distortions is 8.4 times that of the relative price in the benchmark economy. In the data, the relative price of agricultural goods in poor countries relative to the United States is a factor of 7.[17] Second, in the model, most of the drop in labor productivity in agriculture in poor countries is driven by the misallocation of factors across heterogenous farmers. To see that we note that applying the share of farms by size in the farm-size distortions economy to the labor productivity across farm sizes in the benchmark economy implies a drop in productivity of only a factor of 2.7 (compared to a 4-fold drop in the accounting performed in Appendix A). This is less than 6% of the 46.5-fold drop in agricultural productivity in the farm-size distortions experiment.

A Measure of Agricultural Distortions Are there empirically observable farm-size distortions that can generate a quantitatively large drop in both farm size and productivity? This is a tall order, especially when put in the context of the broad literature on misallocation and productivity. Our approach is to exploit crop-level distortions and their relationship to typical operational farm size to obtain a summary measure of farm-size distortions across countries.

[17]The relative price data is from Rao (1993) as processed and analyzed by Restuccia, Yang, and Zhu (2008). We note that while the implications of the model on relative prices are not far from the data, there is less testable content in these observations than what may at first appear. The reason is that in the context of the calibrated model, aggregate price distortions have a first order impact on prices and only second order impact on allocations (an extreme case is when $\phi \to 0$ implying that allocations in agriculture are independent of prices).

Table 6: Effects of Farm-Size Distortions

	Aggregate Factors	+Farm-Size Distortions	Data
Employment in Agriculture N_a (%)	16.6	65.2	65.3
Average Farm Size (AFS)	8.6	34	34
Labor Prod. in Agriculture ($\frac{Y_a}{N_a}$)	11.2	46.5	46.7
Aggregate Labor Productivity ($\frac{Y}{N}$)	7.6	17.0	19.2

Note: Average farm size, real labor productivity in agriculture and aggregate labor productivity are reported as the ratio between the benchmark economy and the poor economy. Farm-size distortions represent the model with aggregate factors and farm-size distortions given by the tax function $P(s) = 1 - 1/\exp(\psi s)$ where $\psi = 406$ is calibrated to match the factor difference in average farm size of rich relative to poor countries.

To do this, we use internationally comparable data on agricultural distortions, available from the World Bank through the "Distortions to Agricultural Incentives" (DAI) project, and the associated database (for details see, Anderson and Valenzuela, 2008).[18] The DAI database uses detailed price and output data, by agricultural product, to measure government induced policy distortions faced by farmers in a wide range of countries. The measure of agricultural distortions we focus on, known as the nominal rate of assistance (NRA), is the gap by which government policy alters the return to farmers from what it would be without government intervention. Essentially, if positive, the NRA for a product is a subsidy to the farmers of that product, and if negative, a tax. The NRA is meant to capture domestic direct taxes and subsidies to farmers, trade taxes (e.g., import tariffs, export subsidies), and government intervention in the foreign exchange market (e.g., multi-tier exchange rate regimes). The NRA for a covered product is calculated as the percentage by which the domestic farm-gate price is above the international price of a similar product. If the product is not traded then it only includes the domestic taxes/subsidies. Notably, these measures are net of transportation and distribution costs. The DAI database also constructs an NRA for total agriculture as the sum of an output weighted average of the covered product-NRA, an estimate on the rate of protection

[18]This database extends earlier efforts to document agricultural distortions (Krueger, Schiff, and Valdes, 1988) to a larger set of countries (77 in total), a longer period of time (1955-2007), and a more comprehensive set of distortionary measures.

for non-covered farm products, and non-product specific assistance.

A well known fact that has emerged from the World Bank's DAI project is that on average poor countries tax agriculture. This observation is based on the aggregate agriculture NRA, which is typically used as an empirical summary measure of distortions in the literature. For the countries in our sample, the ratio of the average gross tax rate (negative NRA) in poor countries relative to rich countries is a factor of 2.6. However, what is critical in generating misallocation in the model is not the average tax rate but how taxes vary across producers with different productivity and hence size. While this information is not readily available in the DAI database, we use the variation of agricultural distortions across covered products within countries and how they correlate with typical operational size.

More specifically, to uncover farm-size distortions across countries from the DAI dataset we implement the following strategy. First, we obtain measures of taxes/subsidies (NRAs) at the crop-level by country from the DAI database. Not only are the average taxes high in poor countries, but there is also substantial dispersion of crop-level taxes within poor countries, with an average standard deviation of 0.33. Second, we use U.S. Agricultural Census data to derive an empirical relationship between average farm size and the type of crop a farm is producing (e.g., farm size is larger for sugar and rice farms than for maize and vegetable farms). Third, under the assumption that this relationship applies to all countries, we use the crop-specific taxes by country to construct farm size-dependent taxes for poor countries relative to the benchmark. In Figure 6, we plot for each product, the average tax rate across poor countries relative to the United States, against U.S. average farm size by crop, ordered from lowest to highest. The implied pattern is striking: taxes are systematically related to the product operational scale in the United States, with a correlation of 0.6. That is, products produced on a larger scale in the United States are taxed more heavily in poor countries relative to products that are produced on a smaller scale in the United States.

Fourth, the farm-size taxes are then approximated by the following generalized tax function,

$$\tau_s = P(s) = 1 - \frac{\psi_0}{\exp(\psi_1 s)},$$

which allows for different means and correlation between size and productivity. We note that $\psi_0 = 1$ and $\psi_1 = \psi$ deliver the functional form used in our generic distortions experiment above.

Next, we ask what share of the observed variation between rich and poor countries in farm size and productivity can these measurable farm-size distortions account for? We calibrate ψ_0 and ψ_1 to minimize the distance between the model and the data for three moments from the tax rates we presented above: (a) a mean gross tax rate that is 2.6 of the gross tax rate in the benchmark economy; (b) a standard deviation of taxes of 0.33; and (c) a correlation between tax rates and size of 0.6. The calibrated parameter values match the target moments very well, within 2 decimal places. In the first column of Table 7 we present the results from feeding in the model the aggregate factors and the empirically disciplined tax function. The model produces considerable changes in the key variables of interest relative to the aggregate factors only case: the share of employment in agriculture increases to 33.8% from 16.6%, the average farm size disparity rises from 8.6 to 17.6, and the agricultural productivity gap rises from 11.2 to 23.9. Overall, the model with the empirical farm-size distortions is able to generate 50% of the variation in the allocation of employment, average farm size, and productivity between rich and poor countries, with about half of this accounted for by aggregate factors.

The covariance of taxes with farm size is key in generating misallocation and the substantial effects on average farm size and productivity. To illustrate this point, we conduct another experiment where all farmers are taxed at a flat rate equal to the average tax rate in the experiment with the empirical measure of distortions. The results of the experiment with aggregate factors and the flat tax rate are presented in the second column of Table 7. Introducing an aggregate tax has virtually no effect on size and productivity relative to the case of only aggregate factors. The systematic correlation to farm-level productivity is what generates misallocation and consequently size and

Table 7: Effects of Empirical Measure of Farm-Size Distortions

	Farm-Size Distortions	Flat Tax	Data
Employment in Agriculture N_a (%)	33.8	15.9	65.3
Average Farm Size (AFS)	17.6	8.3	34
Labor Prod. in Agriculture ($\frac{Y_a}{N_a}$)	23.9	11.2	46.7
Aggregate Labor Productivity ($\frac{Y}{N}$)	9.5	7.6	19.2

Note: Average farm size, real labor productivity in agriculture and aggregate labor productivity are reported as the ratio between the benchmark economy and the poor economy. Farm-size distortions represent the model with aggregate factors and empirical farm-size distortions from NRA data (with $\psi_0 = 0.73$ and $\psi_1 = 4.9$). Flat Tax represents an economy with aggregate factors and a common tax to all farms equal to the mean in the empirical farm-size distortions.

productivity effects.

To the best of our knowledge we are the first to utilize the DAI dataset on product-level distortions from the World Bank and relate these distortions to farm size and productivity. Our empirical measure of farm-size distortions has two key desirable attributes: it is a summary measure of agricultural policies that are size-dependent and it is available for a wide cross-section of countries. However, it is important to note that this empirical measure of distortions is limited in that it does not encompass all the distortions that we document in Appendix D. In particular, it only captures explicit distortions that operate through measured prices and leaves out other polices or frictions such as restrictions in land markets and caps to size that tend to affect disproportionately more productive farmers. In the next section, we complement this analysis with specific-observable policies that distort size in a stark way in two case studies in developing countries.

Despite the fact that our empirical measures of distortions do not capture all the size frictions in agriculture in poor countries, when fed into our model they generate a substantial negative impact on farm size and productivity in poor countries, accounting for 50% of the variation in data. The 24-fold drop in agricultural productivity generated by the model is sizeable, especially when compared to the quantitative effects often found in the general misallocation literature. In particular, note that if poor countries were to eliminate all empirical farm-size distortions, labor productivity in agriculture would increase by a factor of more than 2 (1/23.9 vs. 1/11.2). Moreover, there are many mechanisms that are absent in the model that are known to amplify the effects of distortionary policies on outcomes. There are several amplification channels that have been considered in the literature, such as human capital accumulation, endogenous productivity dynamics, selection, among others (see for instance the review of the misallocation literature in Restuccia and Rogerson (2013) and references therein). More specifically, in the context of a model of agriculture and development, selection effects have been explored by Lagakos and Waugh (2013) whereby exogenous differences in productivity are amplified substantially by selection of workers between agriculture and non-agriculture. In quantitative terms, agricultural productivity differences are amplified by a factor of 1.5 with selection (see Table 6 in Lagakos and Waugh). To put this number in perspective, note that if we take the results of the empirical measure of distortions, the implied factor difference in agricultural productivity in a model with selection would increase from 23.9 to 35.9, much closer to the data (46.7-fold difference).

6 Specific Farm-Size Policies

We study the quantitative effects of concrete farm-size policies, land reforms and progressive land taxes, focusing on the institutional detail of the policy change in each case and examining its size and productivity effects.

Land reforms are the most prevalent policy in developing countries distorting farm size. Land reform generically refers to the redistribution of land from large landowners to tenants, smallholders or landless. Such redistribution is implemented through legislation that often involves direct restrictions on size and intervention in the sales and rental markets for land.

We study the most common type of land reform undertaken in practice which is an explicit limit (ceiling) on the maximum size of any agricultural holding. We introduce the ceiling legislation into the model by imposing a constraint on land input demand by farmers ($\ell \leq \ell_{max}$). In equilibrium, profit maximization implies two categories of farmers: unconstrained farmers –those with relatively low ability that would optimally have chosen land input below the ceiling, and constrained farmers –those with relatively high ability that would have chosen land input above the ceiling in the absence of the size constraint. In Appendix B we briefly provide the key conditions that change relative to the benchmark model. In this version of the model, the size constraint reduces total demand for land given prices, leading to a reduction in the price of land to clear the land market and in turn an increase in the demand for land by unconstrained farmers. Thus, the land reform policy leads to a reallocation of resources from high to low productivity farms.

To assess the quantitative effects of the land ceiling policy, we study the 1988 land reform in the Philippines, known as the Comprehensive Agrarian Reform Program (CARP). CARP constitutes an interesting case study because it represents a land reform with a relatively restrictive ceiling (a 1.75 ratio of ceiling to pre-reform average farm size), an extensive coverage in terms of land and beneficiaries, a fairly successful redistribution with most of the targeted land having been redistributed by early 2000s (Philippine Department of Agrarian Reform, 2006). The redistribution covered all agricultural lands (private and public). CARP imposed a ceiling of 5 Ha on land ownership. Land was acquired on both a compulsory and a voluntary-offer-to-sell basis at fair market value. The transferability of the redistributed lands was limited to heirs, the state, and other beneficiaries after 10 years (Saulo-Adriano, 1991). In 1981, the earliest decennial Census of Agriculture prior to the 1988 reform, average farm size was 2.85 Ha. Based on the 2002 Census of Agriculture the post-reform average farm size was 2.01 Ha, implying a drop of 29.6%.

To implement the land reform in our model we consider an economy that is endowed with the aggregate factors (land per capita, capital-output ratio, economy-wide productivity) of the Philippines at the time of the reform in 1988. To replicate the sectoral structure of the Philippines in 1988, without assuming any other farm-size distortions, we also choose the agriculture-specific productivity parameter κ to reproduce a pre-reform share of employment in agriculture of 45.1%. The disparities in aggregate factors between the benchmark economy and 1988 Philippines are: 3.3 in land per capita, 1.38 in capital-output ratio, and 4.2 in non-agricultural productivity. Matching the agricultural employment share requires $\kappa = 1/3.9$. The data sources are provided in Appendix A. We then impose a land ceiling with a restrictiveness ratio of 1.75 on this economy. The first column of Table 8 shows that the ceiling produces an increase in the share of employment in agriculture of over 3 percentage points, a reduction in average farm size of 7.0%, a reduction in agricultural labor productivity of 7.0%, and a reduction in aggregate labor productivity of 5.8%. These effects are all in the anticipated direction. A binding ceiling prohibits farms over the legislated maximum to exist bringing down average size. This causes a misallocation of resources away from large and productive farms causing a drop in agricultural productivity. The drop in agricultural productivity produced by the model is quantitatively consistent with the drop observed in the Philippines immediately after the reform, over 1989-1993 (-7.0% in the model vs. -8.1% in the data).

In evaluating the impact of land reforms, which take time to be fully implemented, many studies rely on time series evidence for the period following the reform. In the context of our model, the evolution of aggregate variables can mask the impact of the reform on size and productivity. In fact, while the land reform has a substantial negative effect on agricultural productivity in the model, the data for the Philippines show an increase in agricultural productivity over the longer period 1988-2000. We introduce the relevant changes in aggregate factors for the Philippines between 1988-2000: (a) a reduction in land per capita of -26.9% and (b) an increase in the capital-output ratio and non-agricultural productivity of 3.8% and 9.9%. Table 8 introduces these factors into the economy after the land reform. Quantitatively, combining these forces with the reform, the model accounts for the salient features of the Philippines' experience over 1988-2000.

In summary: (1) land reforms imposing ceilings on land size reduce not only farm size but also productivity, (2) land per capita is an important determinant of average farm size but not productivity (see column 2 in Table 8), and (3) increases in aggregate factors such as capital accumulation

Table 8: Philippine Land Reform – Changes 1988-2000

	Ceiling	$+\Delta L$	$+\Delta(\frac{K}{Y}, A)$	Data
Employment in Agriculture N_a (%)	48.5	48.6	43.0	37.6
Average Farm Size AFS (%Δ)	-7.0	-32.1	-23.2	-29.6
Labor Prod. in Agriculture $\frac{Y_a}{N_a}$ (%Δ)	-7.0	-7.2	5.2	9.5
Aggregate Labor Productivity $\frac{Y}{N}$ (%Δ)	-5.8	-6.0	13.4	16.4

Note: ΔL denotes the change in land per capita, $\Delta(\frac{K}{Y}, A)$ denotes the changes in capital to output ratio and economy-wide productivity. %Δ denotes percentage change.

and economy-wide productivity, can mask the negative size and productivity effects of land ceilings when assessed using time-series evidence.

The next specific farm-size policy we consider is a progressive land tax. Progressive land taxes are pervasive in developing countries such as Zimbabwe, Pakistan, Brazil, Namibia, among many others. We study quantitatively the 1970s land revenue system in Pakistan. The West Pakistan Land Revenue Act of 1967 required all farmers to pay a (provincial) land tax. According to the 1967 Act, while tax rates were classified by soil type for a village or group of villages (Khan and Khan, 1998), they were not differentiated across farms on the basis of size. A 1976 amendment to this Act, known as the West Pakistan Land Revenue Act 1976, introduced steep progressivity in the land tax system. According to the 1976 Act all irrigated land holdings of up to 5 Ha were exempted from paying a land tax. Among the non-exempt farmers, those with holdings between 5-10 Ha paid the same rates as before, while farmers with holdings between 10-20 Ha were subject to a 50% rate increase, and farmers with over 20 Ha were subject to a 100% increase relative to the previous rates. While we leave the details of this experiment to Appendix C, we note that we follow an approach similar to the land reform experiment. We find that introducing the progressive land tax policy alone to pre-reform Pakistan reduces both farm size and agricultural labor productivity by just over 3%. In the data, in the period following the reform, farm size dropped considerably more and agricultural productivity actually increased. Similar to the case of land reforms, when we incorporate changes in aggregate factors in the period after the reform along with the policy change, the results of the model capture the observed changes in the key variables of interest. The decrease in land per capita amplifies the negative effect of the reform on farm size, while the stellar increase in non-agricultural productivity accounts for the rise in agricultural productivity, masking the negative productivity effects of the progressive land tax.

7 Conclusions

There are substantial differences in farm size across countries. Agricultural production in rich countries is characterized by large farms, whereas in poor countries by small farms. We developed a tractable quantitative framework to organize our understanding of the factors impacting farm size and productivity across countries. Our focus has been on two sets of factors: (a) aggregate factors (land, capital accumulation, and economy-wide productivity), and (b) farm-level policies in poor countries that misallocate resources from large-productive to small-unproductive farms.

A key feature of our analysis is that we quantitatively assess the extent of misallocation in agriculture in poor countries using observable policy measures. We do this in two ways. First, for a cross-section of countries we introduce an empirical summary measure of farm-size distortions by exploiting the variation in crop-level price distortions within countries. We find that our model with aggregate factors and our empirical measure of distortions can account for half of the gaps in farm size and productivity between rich and poor countries. From this just under half is accounted for by aggregate factors alone. Second, we study specific policies that generate misallocation. We study a land reform that caps size in the Philippines and progressive land taxes in Pakistan. We find that each policy alone can generate non-trivial size and productivity effects but that these effects can be masked by the evolution of aggregate factors in the time-series data. We conclude that understanding farm-size differences may provide a key stepping stone towards understanding the large differences in agricultural labor productivity and consequently aggregate labor productivity between rich and poor countries.

Our model was constructed to mainly address differences across countries at a point in time and as a result abstracts from features that could be pertinent in a time series analysis such as capital accumulation. Nevertheless, it would be of interest to examine the importance of aggregate factors in understanding the substantial increases in farm size and productivity in developed countries. As a first pass, we have explored whether our model with aggregate factors can account for the 3-fold increase in average farm size in the United States from 1929 to 1990. Feeding in the change in land per capita, capital, and economy-wide and sector-specific productivity we find that the model roughly reproduces the reallocation of labor across sectors and the entire increase in average farm size observed for the United States. We take this to suggest that the model has the potential to account for the behavior of the U.S. over time but leave a more detailed analysis of the time series implications for the U.S. and other individual countries for future research.

Our quantitative analysis has abstracted from several institutions and policies that are important in practice in determining the allocation of land across farms in poor countries. For instance, as prevalent as land ceilings are, they are distinct from episodes of massive redistribution of land that effectively replace experienced more able farmers and large-scale operations with inexperienced farmers and government organized small-scale farms. These drastic redistributions of land coupled with imperfections in land markets (e.g., limited property rights and lack of land titles) are likely to be an important obstacle to size and productivity in poor countries (see for instance Bardhan and Udry, 1999 and Goldstein and Udry, 2008). A related issue is to explicitly consider amplification channels such as selection into agriculture and how this may interact with institutions and policies in poor countries. Finally, it would be interesting to study the size and productivity effects of land policies for particular developing countries over time using micro data. Such an analysis could shed light on the importance of changes in size within farms as compared to reallocation across sizes, controlling for farm location.

References

Acemoglu, D. and V. Guerrieri (2008), "Capital Deepening and Non-Balanced Economic Growth," *Journal of Political Economy* 116(3), 467-498.

Adamopoulos, T. (2008), "Land Inequality and the Transition to Modern Growth." *Review of Economic Dynamics* 11(2), 257-282.

Adamopoulos, T. (2011), "Transportation Costs, Agricultural Productivity, and Cross-Country Income Differences," *International Economic Review* 52(2), 489-521.

Anderson, K., and Valenzuela, E. (2008), *Estimates of Global Distortions to Agricultural Incentives, 1955 to 2007*, Washington, DC: World Bank.

Bardhan, P., and Udry, C. (1999), *Development Microeconomics*, New York: Oxford University Press.

Berry, R.A. and W.R. Cline (1979), *Agrarian Structure and Productivity in Developing Countries*, Baltimore: Johns Hopkins University Press.

Binswanger, H.P. (1974), "The Measurement of Technical Change Biases with Many Factors of Production," *American Economic Review* 64(6), 964-976.

Bridgman, B., M. Maio, J. Schmitz and A. Teixeira (2012), "Why Has Puerto Rico Performed So Poorly? Lessons from Its Sugar Manufacturing Industry," Mimeo.

Buera, F., and J. Kaboski (2012a), "The Rise of the Service Economy," *American Economic Review* 103(6), 2540-2569.

Buera, F., and J. Kaboski (2012b), "Scale and The Origins of Structural Change," *Journal of Economic Theory* 147(2), 684-712.

Caselli, F. (2005), "Accounting for Cross-Country Income Differences", *Handbook of Economic Growth, Volume 1*, P. Aghion and S. Durlauf (eds.), Elsevier, Ch. 9, 679-741.

Caselli, F. and W.J. Coleman II (2001),"The US Structural Transformation and Regional Convergence: A Reinterpretation", *Journal of Political Economy* 109(3), 584-616.

Chanda, A., and C.-J. Dalgaard (2008), "Dual Economies and International Total Factor Productivity Differences: Channelling the Impact from Institutions, Trade and Geography," *Economica* 75(300), 629-661.

Cornia, G.A. (1985), "Farm Size, Land Yields and the Agricultural Production Function: An Analysis for Fifteen Developing Countries," *World Development* 13(4), 513-534.

Deininger, K. (2003), *Land Policies for Growth and Poverty Reduction*, World Bank Policy Research Report, Washington, DC.

Duarte, M., and D. Restuccia (2010), "The Role of the Structural Transformation in Aggregate Productivity," *Quarterly Journal of Economics* 125(1), 129-173.

Easterly, W. (2001), "The Middle Class Consensus and Economic Development," *Journal of economic growth* 6(4), 317-335.

Eastwood, R., M. Lipton, and A. Newell (2010), "Farm Size," in *Handbook of Agricultural Economics, Volume 4*, Evenson, R. and Pingale, P. (eds.) North Holland, pp.3323-3397.

Echevarria, C. (1997), "Changes in Sectoral Composition Associated with Economic Growth", *International Economic Review* 38(2), 431-452.

Engerman, S. L. and Sokoloff, K. L. (2000), "History Lessons: Institutions, Factors Endowments, and Paths of Development in the New World," *The Journal of Economic Perspectives*, 217-232.

Foster, A. D., and Rosenzweig, M. R. (2011), "Are Indian Farms Too Small? Mechanization, Agency Costs, and Farm Efficiency," manuscript, Yale University.

Gallup, J.L., and J.D. Sachs, with A. Mellinger (1999), "Geography and Economic Development," Center for International Development, Harvard University Working Paper No.1.

Galor, O., Moav, O., and Vollrath, D. (2009), "Inequality in Landownership, the Emergence of Human-Capital Promoting Institutions, and the Great Divergence." *The Review of Economic Studies* 76(1), 143-179.

Goldstein, M., and Udry, C. (2008), "The Profits of Power: Land Rights and Agricultural Investment in Ghana," *Journal of Political Economy* 116(6), 981-1022.

Gollin, D., S.L. Parente, and R. Rogerson (2002), "The Role of Agriculture in Development," *American Economic Review: Papers and Proceedings* 99(2), 160-164.

Gollin, D., S.L. Parente, and R. Rogerson (2004), "Farm Work, Home Work, and International Productivity Differences," *Review of Economic Dynamics* 7(4), 827-850.

Gollin, D., S.L. Parente, and R. Rogerson (2007), "The Food Problem and the Evolution of International Income Levels," *Journal of Monetary Economics* 54(4), 1230-1255.

Gollin, D., D. Lagakos, and M. Waugh (2011), "The Agricultural Productivity Gap in Developing Countries," Mimeo, Arizona State University.

Grigg, D. (1966), "The Geography of Farm Size A Preliminary Survey," *Economic Geography* 42(3), 205-35.

Guner, N., G. Ventura, and Y. Xu (2008), "Macroeconomic Implications of Size-Dependent Policies," *Review of Economic Dynamics* 11(4), 721-44.

Herrendorf, B., and T. Schoellman (2011), "Why is Labor Productivity so Low in Agriculture?" Mimeo, Arizona State University.

Hsieh, C.T., and P. Klenow (2009), "Misallocation and Manufacturing TFP in China and India," *Quarterly Journal of Economics* 124, 1403-1448.

Khan, M.H., and M.S. Khan (1998), "Taxing Agriculture in Pakistan," IMF Paper on Policy Analysis and Assessment, IMF PP AA/98/3.

Kongsamut, P., S. Rebelo, and D. Xie (2001), "Beyond Balanced Growth", *Review of Economic Studies* 68, 869-882.

Krueger, A. O., Schiff, M., and Valdes, A. (1988), "Agricultural Incentives in Developing Countries: Measuring the Effect of Sectoral and Economy-wide Policies," *The World Bank Economic Review* 2(3), 255-271.

Kuznets, S. (1971), *Economic Growth of Nations: Total Output and Production Structure*, Cambridge, MA: Harvard University Press.

Lagakos, D. (2009), "Superstores Or Mom and Pops?: Technology Adoption and Productivity Differences in Retail Trade," Federal Reserve Bank of Minneapolis, Research Department.

Lagakos, D., and M. Waugh (2013), "Selection, Agriculture, and Cross-Country Productivity Differences," *American Economic Review* 103(2), 948-980.

Lucas, R. (1978), "On the Size Distribution of Business Firms," *Bell Journal of Economics* 9(2), 508-23.

Ngai, R.L. and C. Pissarides (2007), "Structural Change in a Multi-Sector Model of Growth", *American Economic Review* 97(1), 429-443.

Rao, P.D.S. (1993), *Intercountry Comparisons of Agricultural Output and Productivity*, Rome: Food and Agriculture Organization of the United Nations.

Restuccia, D. and R. Rogerson (2008), "Policy Distortions and Aggregate Productivity with Heterogeneous Establishments," *Review of Economic Dynamics* 11(4), 707-720.

Restuccia, D., and Rogerson, R. (2013), "Misallocation and Productivity," *Review of Economic Dynamics* 16(1), 1-10.

Restuccia, D., D. T. Yang, and X. Zhu (2008), "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis," *Journal of Monetary Economics* 55(2), 234-250.

Saulo-Adriano, L. (1991), "A General Assessment of the Comprehensive Agrarian Reform Program," Working Paper Series No.91-13, Philippine Institute for Development Studies.

Schultz, T.W. (1953), *The Economic Organization of Agriculture*, New York: McGraw-Hill.

Valentinyi A. and B. Herrendorf (2008), "Measuring Factor Income Shares at the Sectoral Level," *Review of Economic Dynamics* 11, 820-835.

Vollrath, D. (2009), "How Important are Dual Economy Effects for Aggregate Productivity?" *Journal of Development Economics* 88(2), 325-334.

Wiebe, K., Soule, M. J., Narrod, C., and Breneman, V. E. (2000), "Resource Quality and Agricultural Productivity: A Multi-Country Comparison," manuscript, U.S. Department of Agriculture.

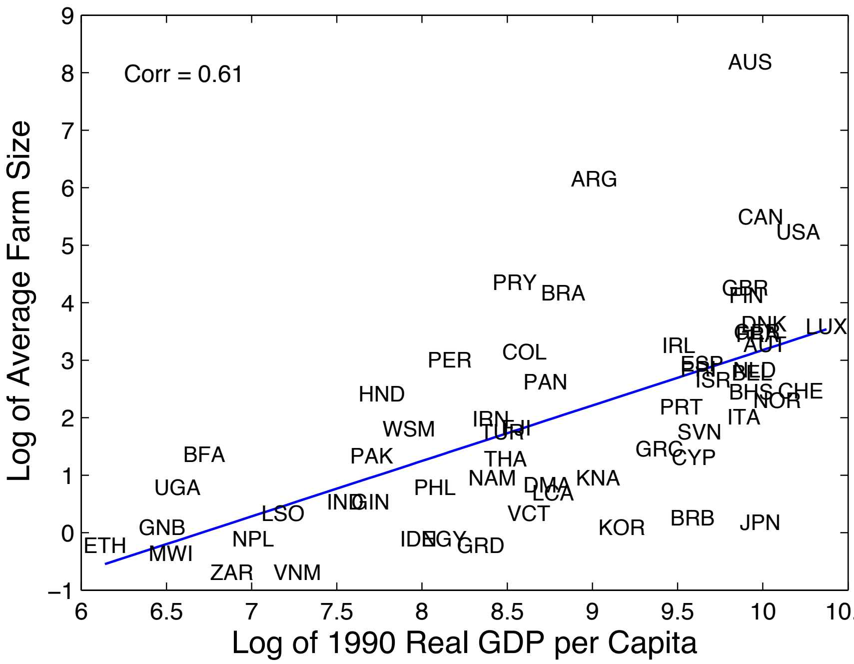


Figure 1: Average Farm Size across Countries

Panel A: Small Farms (<5 Ha)

Panel B: Large Farms (>20 Ha)

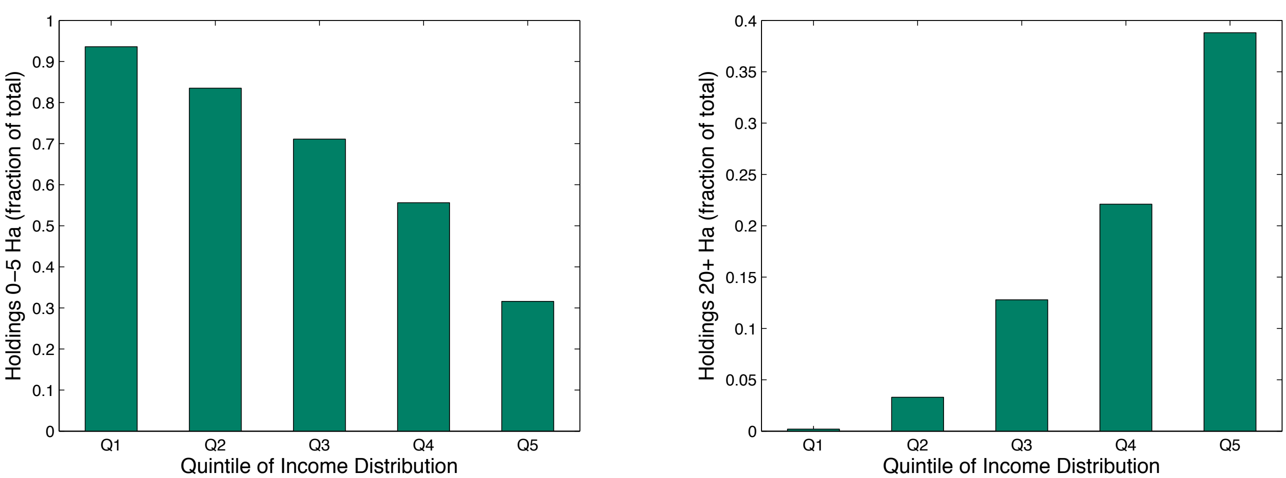


Figure 2: Share of Small and Large Farms across Countries

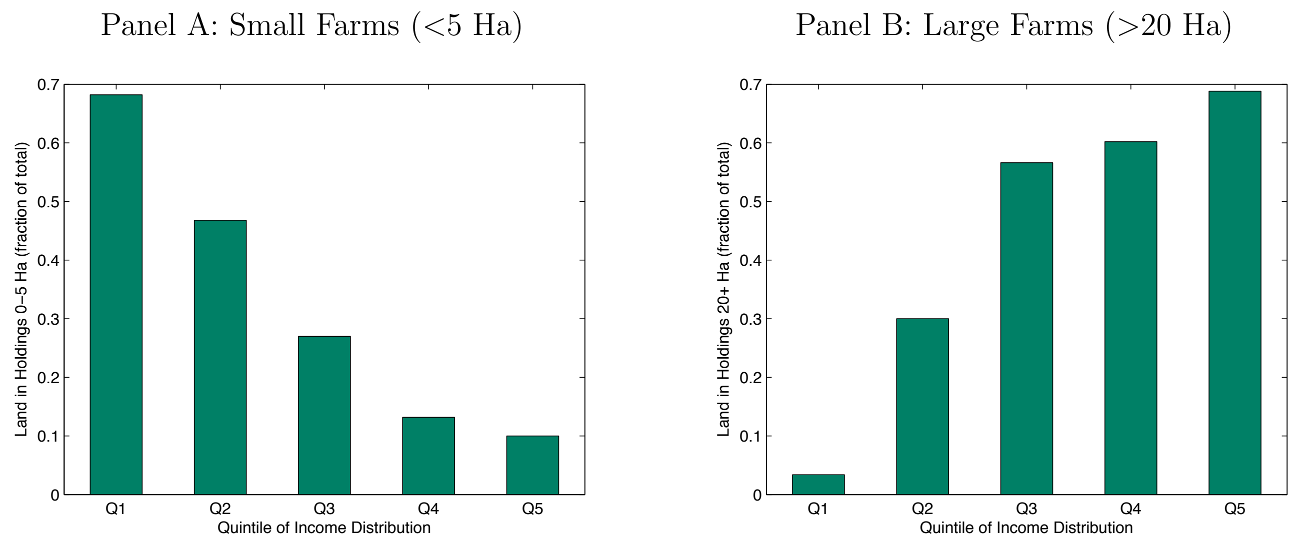


Figure 3: Share of Land in Small and Large Farms across Countries

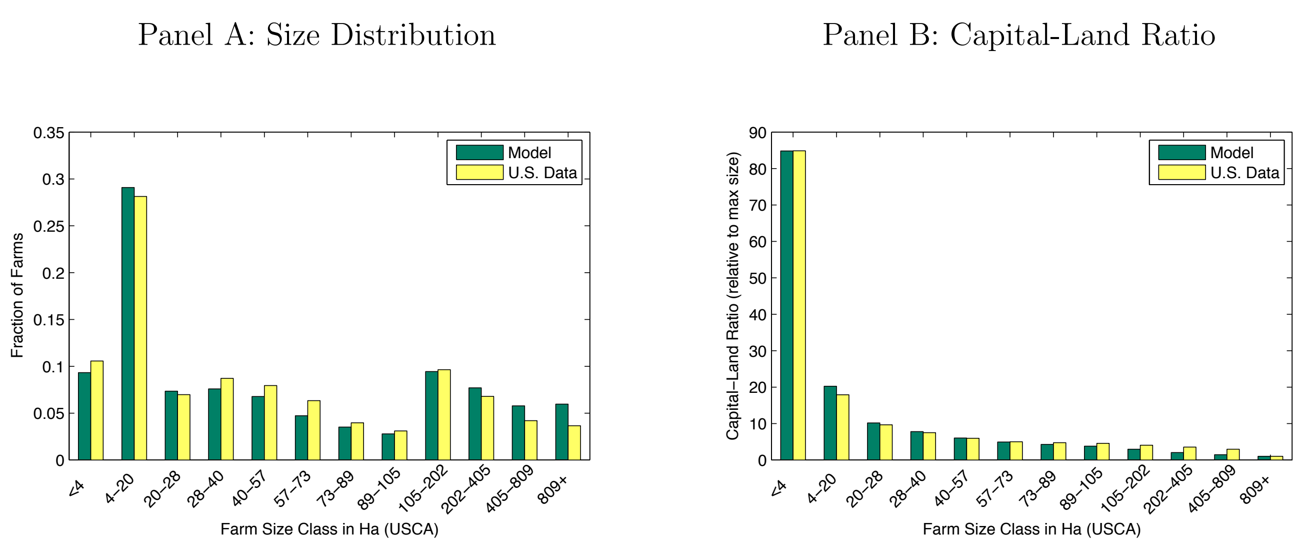
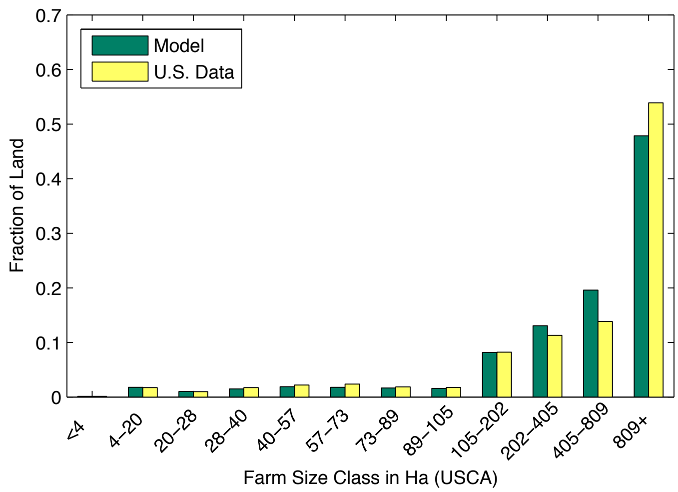
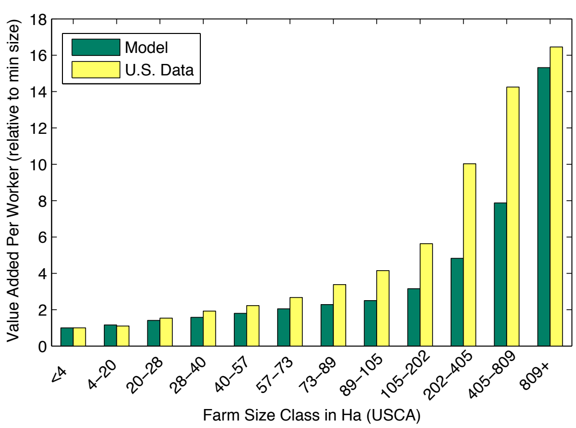


Figure 4: Calibrated Variables by Farm Size

Panel A: Land Distribution



Panel B: Value Added per Worker



Panel C: Value Added per Hectare

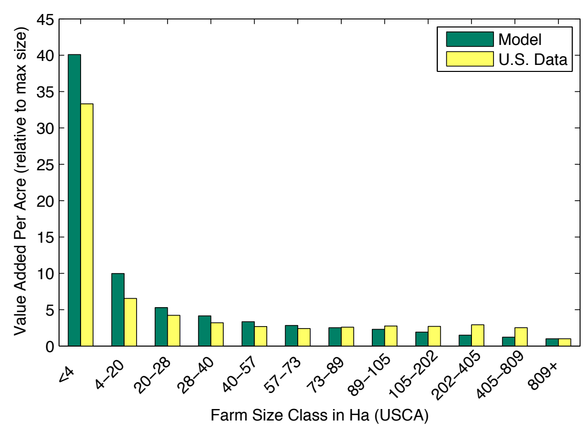


Figure 5: Other Variables by Farm Size

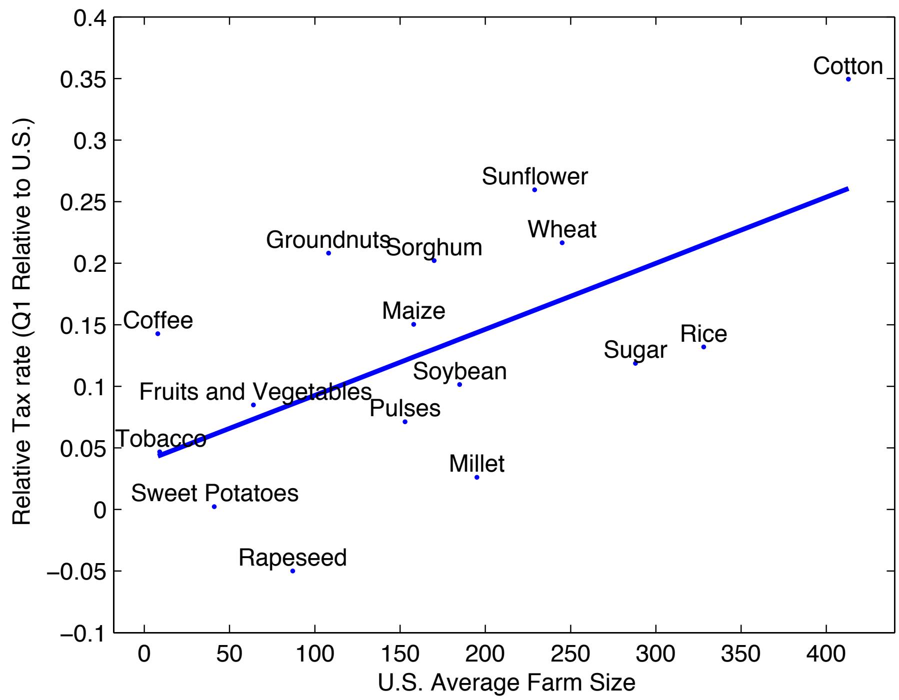


Figure 6: Empirical Farm-Size Distortions