Land Reform and Productivity: A Quantitative Analysis with Micro Data†

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Abstract

We assess the effects of a major land policy change on farm size and agricultural productivity, using a quantitative model and micro-level data. In particular, we study the 1988 land reform in the Philippines, which was an extensive land redistribution program that imposed a ceiling of 5 hectares on all land holdings while at the same time severely restricting the transferability of the redistributed farm lands. Our micro data allow us to track a set of Philippine farmers, before and after the reform, offering rich input and output information at the parcel-level. This data allows us to obtain precise measures of farm-level productivity, and study how the choices of farmers changed following the reform. We decompose the change in aggregate agricultural productivity, following the reform, into: (a) a reallocation effect, whereby farming activity is shifted from large farms to small farms and (b) a within-farm effect. We find that the source of the within-farm effect is a change in the crop mix between cash crop and food crops. We develop a quantitative model with a non-degenerate distribution of farm sizes that features an occupational-choice decision for the farmer. A farm operator chooses between two technologies: a "cash crop" and a "food crop" technology. The cash crop technology has higher TFP but requires a higher fixed cost. A land reform reduces aggregate agricultural productivity not only by reallocating resources from large/high productivity farms to small/low productivity farms, but also by altering how farmers sort themselves across technologies. We calibrate the model to the agricultural sector of the Philippines before the reform. We find that the land reform reduces average farm size by 9% and agricultural productivity by 5%. From the overall productivity effect, 60% is accounted for by the misallocation channel, while the rest by the selection channel. We also find that other changes occurring alongside the reform can mask the effects of the reform in time series data.

JEL classification: O11, O14, O4.
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1 Introduction

A key challenge in the literature on misallocation and development is to measure quantitatively how specific establishment-level policies affect productivity at the industry level. For the very poor countries in particular, understanding how farm-level policies affect aggregate agricultural productivity is an especially pressing issue. This is because the poorest countries: (a) are particularly unproductive in agriculture and devote a lot of resources to it, when compared to rich countries (Restuccia, Yang, and Zhu, 2008) and (b) on average undertake farming at a much smaller operational scale than rich countries (Adamopoulos and Restuccia, forthcoming).

The purpose of this paper is to assess the effects of a major land-policy change on farm size and agricultural productivity, using a quantitative model and micro-level data. In particular, we study the 1988 land reform in the Philippines, known as the Comprehensive Agrarian Reform Program (CARP). CARP was an extensive land redistribution program that imposed a ceiling of 5 hectares on all land holdings, while at the same time severely restricting the transferability of the redistributed farm lands. We combine two sources of micro data to study the size and productivity effects of the land reform: (a) Decennial Agricultural Census Data, which offer a complete enumeration of farms, land and labor inputs at the farm level in two separate cross sections, before and after the reform; (b) Philippines Cash Cropping Project, a panel of farm survey data, which tracks a much more limited number of rural households before and after the reform but offers a wealth of information on all inputs and outputs at the parcel and farm level. Combining these two sources of micro data allows us to measure choices on farm size, input mix, output mix, and productivity changes before and after the reform. Relative to previous studies this allows us to study the channels through which land policy affects agricultural productivity at the industry level. In particular, we can decompose the change in aggregate agricultural productivity into: (a) a reallocation effect, whereby farming activity is shifted from large farms to small farms, and (b) a within-farm effect, whereby productivity changes at the farm level over time. Given that we observe outputs and inputs as well as their prices separately at the parcel level, we do not have to rely on industry deflators to compute farm-level productivity.

A nice feature of using a panel of farm surveys is that it permits tracking a particular farmer over time and therefore it allows the researcher to also observe the source of the within-farm effect following the reform. Looking inside the farm, we can address whether the farmer is doing something different after the policy change compared to before: e.g. change in the crop mix or change in the input mix. Further, there will be farmers that were initially below the land reform ceiling (and still are) and those that were initially above and are now brought down as a result of the reform. This type of exercise in a given country over time controls for farmer ability and for location since land quality and climate can be kept constant. Our data indicate a change in the crop mix between food cropping and cash cropping, for the same set of farmers.

To study the effects of the Philippine land reform, we develop a quantitative model that builds on the model of farm size of Adamopoulos and Restuccia (forthcoming). This is a two-sector model of agriculture and non-agriculture that features a non-degenerate distribution of farm sizes. Farm size is endogenized by embedding a Lucas (1978) span-of-control model of firm 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. In this model farmer-level productivity is drawn from a known distribution but is fixed, that is the farmer cannot take any action to affect the productivity of the farm. We extend the model of farm size in Adamopoulos and Restuccia (2011) by including an occupational choice decision for the farmer. The farmer chooses whether to become a hired worker or an operator of a farm, and as an operator can choose between two technologies, a "cash crop" technology and a "food crop" technology. The cash crop technology has higher TFP but also requires a higher fixed operating cost. The motivation for this broad technology-choice specification is dictated by our farm survey data.

In this framework, in the absence of any idiosyncratic distortions the farm size distribution and the allocation of farmers across occupations and technologies is optimal. A land reform that imposes a ceiling reduces farm size and aggregate agricultural productivity through two channels: (1) by reallocating resources from large/high productivity farms to small/low productivity farms - the misallocation effect, and (2) by altering how farmers sort themselves across occupations and across technologies - the selection effect. In particular the selection effect induced by the land reform, consists of an increase in the number of operators and a technology switch towards the higher productivity cash crop. Then at the sectoral level productivity drops because overall there are now more low ability farmers operating farms, while the ones that switch to larger scale cash cropping face a binding ceiling on their operations. Both the misallocation channel and the selection channel reduce aggregate agricultural productivity.

We calibrate the model to the agricultural sector of the Philippine economy before the reform, matching in particular the farm and land distributions from the survey data prior to the reform. We discipline the parameters of the technology choice from the farm survey data, on farm cropping patterns. In our baseline quantitative experiment we impose the land reform policy limiting farm size to 5 hectares as if this is the only thing happening and and we study the consequences of this policy for average farm size, aggregate agricultural productivity, and the distribution of farm-level productivities. We find that the land reform alone reduces average farm size by 9.3% and aggregate agricultural productivity by 5%. We then decompose the change in productivity into a reallocation effect and a selection effect. We find that out of the 5% drop in productivity, 60% is accounted for by the misallocation channel directly.

We also examine how farm size and productivity are affected when we combine the ceiling with the other changes occurring alongside the reform over the same period, such as overall productivity growth in the economy (captured by productivity growth in non-agriculture), change in land per capita, change in the relative price of cash to food crops, crop-specific productivity changes. We find that taking these changes into account can mask the effects of the land reform. As a result when looking at times series data one might not observe the negative effect of the reform on size and productivity. In this sense, it is useful to look at the land reform through the lens of the model, because it allows you to disentangle the impact of the land reform from other factors.

2 Land Reforms

We focus on a specific policy that distorts farm size in a stark way: land reform. By land reform here we mean the redistribution of land from land-rich (e.g. large landowners) to land-poor (e.g. tenants, smallholders, landless). In practice many land reforms involved the legislation of a maximum ceiling on land holdings, with a redistribution of the land in excess of the ceiling. Often such land reforms were accompanied by restrictions on the land sales and land rental markets. Land reforms have been very prevalent in developing countries in the second half of the 20th century.

In Table 1 we have compiled a set of land reforms that have been implemented since the 1950s for countries for which we were able to obtain data. The middle column indicates the period of the land reform. The column to the right provides the explicit legislated ceiling imposed by the reform. This ceiling per se might not be a good description of how restrictive or binding the reform was, as these countries differ in their pre-reform average farm size. One way to measure the restrictiveness of the reform is to look at the ratio of the ceiling to the pre-reform average farm size. This restrictiveness ratio varies quite a bit across reforms: e.g. 1.75 in the Philippines, 9 in Bangladesh. Of course these reforms can also vary in the degree of enforcement. In the first column we calculate the change in average farm size before and after the reform using census data from the World Census of Agriculture (and where such data are absent from the respective national agricultural censuses). What is noteworthy, is that in all these cases average farm size dropped following the reform. This should be put in perspective, since the tendancy for average farm size is to increase over time,

Table 1: Some Land Reforms

Country	Change in AFS (%)	Land Reform Period	Ceiling on Land Size (Ha)
Bangladesh	-49.1	1984	8
Ethiopia	-44.1	1975	10
India	-25.8	by early 1970s	by province: 4-53
Korea	-21.5	1950	3
Pakistan	-11.5	1972, 1977	61, 40
Sri Lanka	-26.2	1972	10-20
Philippines	-29.6	1988	5

as a country goes through the process of structural transformation and individuals move out of agriculture into non-agriculture. This is strongly supported by examining the trends in average farm size of today's developed economies. For example, in the U.S. average farm size increased almost 4-fold over 1880 - 1997, and in Canada more than 7-fold over 1871 - 2006.

Philippine Land Reform

It is difficult to draw general conclusions about the effects of land reforms from the information in Table 1, given that such forms differ in a variety of dimensions. Instead of examining a number of land reforms, our approach here is to quantitatively assess the effects of a particular land reform by focusing on the institutional detail of that reform and using detailed micro data. We study the 1988 land reform in the Philippines, known as the Comprehensive Agrarian Reform Program (CARP). The reform imposed a ceiling of 5 ha on all agricultural holdings, and redistributed the land in excess of the ceiling. Land acquisition took place on a voluntary and compulsory basis at fair market value. A characteristic of this reform was that it restricted the transferability of the redistributed lands. In particular, it precluded the transfer of the redistributed land except to an heir or the government and only after 10 years. There are a few reasons that we consider the Philippines. First, it was an extensive and comprehensive reform: it targeted 80% of the country's total farm land; included public and private lands, as well as all crops. Second, it was a "successful" reform: 80% of the targeted land had been redistributed by the early 2000s. Third, the reform was restrictive. From the countries that we were able to obtain data for in Table 1 it was the most restrictive, with a restrictiveness ratio of 1.75. Finally, it is a relatively recent reform, and as a result good data exists before and after the reform.

3 Data Analysis

To study the effects of the Philippine land reform on farm size and productivity we use aggregate and micro-level data. The aggregate sectoral data allow us to observe what has happened to farm size and agricultural productivity for Philippine agriculture as a whole. The micro level data allow us to conduct a deeper investigation of the sources of the changes in farm size and productivity.

We use two sources of micro-level farm data for the Philippines: (a) the decennial agricultural censuses, and (b) the Philippines Cash Cropping Project. The decennial agricultural censuses are undertaken by the National Statistics Office (NSO) of the Republic of the Philippines (we use the 1981 and 2002 Census of Agriculture) and provide a complete enumeration of farms covering the entire country. Even though the census data is comprehensive it does not provide information on outputs or other inputs (besides land and hired labor) at the farm level. In order to calculate productivity with precision at the farm-level, in addition to the Census data, we use more detailed survey data. In particular, we use household survey data from the International Food Policy Research Institute (IFPRI), known as the Philippines Cash Cropping Project (PCCP) which was conducted in the Bukidnon province on the island of Mindanao.[1]

[1]Mindanao is the second largest island (after Luzon) in the Philippines, located in the south-east of the country. Bukidnon is the food basket of the island. Compared to Luzon, Mindanao has a more even distribution of rainfall throughout the year, is not on the path of typhoons, and has lower population density.

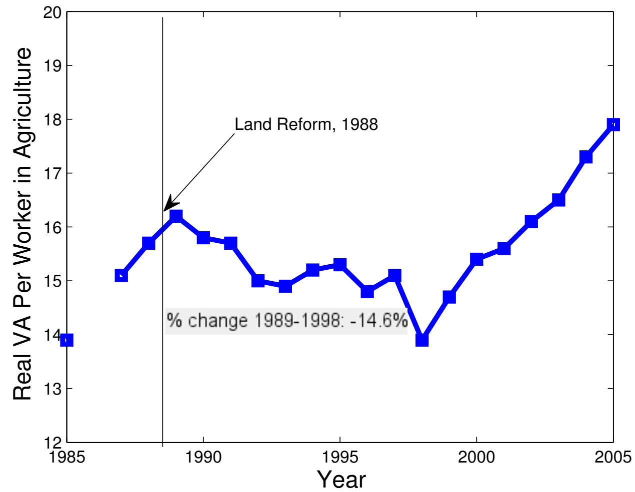

Figure 1: Agricultural Labor Productivity

3.1 Agricultural Productivity in the Philippines

Since we are interested in studying the effect of the reform on productivity we first ask, how has agricultural labor productivity evolved in the Philippines in the periods before and after the reform? In Figure 1 we plot agricultural labor productivity over 1985-2005. Agricultural labor productivity is calculated as gross value added in agriculture, fishery, forestry in 1985 constant prices (from the Bureau of Agricultural Statistics, Philippines) over the economically active population in agriculture, forestry, fishing (from ILO, Labor Force Survey, Table 1C).

We also indicate with a vertical line the timing of the legislation of the land reform. In the period following the reform agricultural productivity dropped by as much as 14.6% (over 1989-1998). This drop should be put into perspective as there are other changes that are occurring in the economy besides the land reform. For example, there is general growth: labor productivity in the non-agricultural sector was rising (number). If one looks over a longer horizon, agricultural productivity increases by 12.5% over 1988-2005, and 28.6% over 1985-2005. Thus aggregate data, may confound the effects of the land reform. Our goal here is to use a simple model to disentangle the effects of the reform from other changes that may be occurring along side the reform in the Philippines over the same period.

3.2 Changes in Farm Size - Census Data

We note that in the census data a farm is an operational unit regardless of ownership or legal status. A farm may consist of more than one parcels, as long as all are under the same management and use the same means of production.

In the last decennial census before the reform (1981) average farm size was 2.85 ha. By the 2002 census (there was a decennial census in 1991 but given that the land reform had largely not been implemented by that time we look at the next census) average farm size had dropped to 2.01 ha, a drop of 29.6%. This drop in average scale of operation is also evident when examining the farm size distribution in Figure 2, which shows the share of farms within each size category for 1981 and 2002. As is clear there has been a shift in the mass of farms from larger scale farms (2+ ha) to smaller scale farms (less that 1 ha) over 1981-2002.

In Figure 3 we plot the share of farm land operated by farms within each farm size category. This graph also indicates a shift in land mass from larger farms (2+ ha) to smaller farms (0-2 ha).

3.3 Survey Micro Data

In the PCCP survey data 448 households were interviewed in four rounds over 1984-85 (just before the reform). Then the original households and their children were interviewed again in five rounds (seasons) over 2002-03.[2] Although the number of farms is much more limited than in the census,

[2] Bouis and Haddad (1990) contains a detailed description of the project and an analysis of the 1984-85 data.

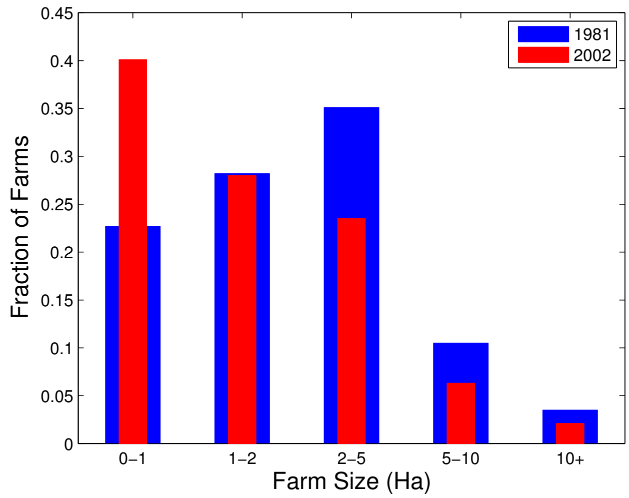

Figure 2: Changes in Farm Size Distribution - Census

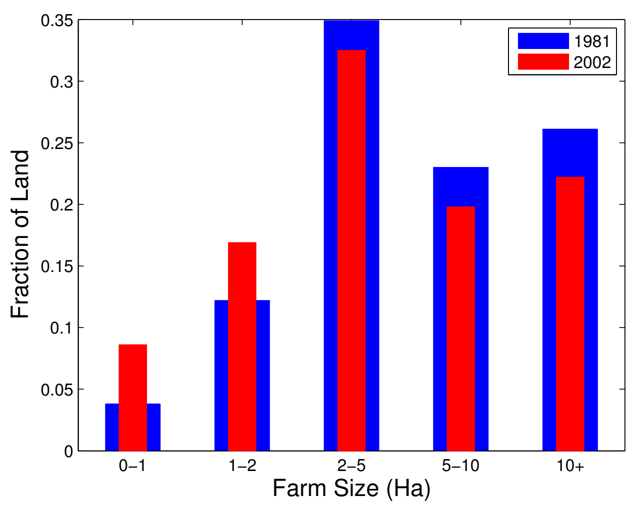

Figure 3: Changes in Land Share by Size - Census

it tracks the same set of households before and after the reform. The survey offers a wealth of information, with precise and detailed measurement of inputs and outputs at the parcel and farm level.[3] There are two important benefits of using this data for production-unit productivity calculations. First, in contrast to many establishment-level studies that have access only to information on sales and input expenditures by establishment, we observe quantities and prices of outputs and inputs separately at the parcel-level. This allows us to obtain more precise measures of real productivity without having to resort to using industry level deflators. Second, the fact that we observe this information at the parcel level, and we know which parcels are operated by which households, we are able to accurately aggregate productivity up to the farm-level. To appreciate the benefit of this contrast it to many other industry studies which only observe information at the plant or establishment level, without being able to identify the common firm to which several plants may belong.

We use the PCCP survey data in order to understand how the land reform affects productivity at the farm-level. In particular, how does the land reform alter the farmer's allocation of resources across activities within the farm? This within farm effect, in combination with the more obvious reallocation effect, will allow us to get a better handle of the effects of the reform for agricultural productivity in the Philippines over time.

In 1984-85, when the first rounds of the survey were conducted, the study area was primarily engaged in corn, rice, and sugarcane production plus some other crops such as bananas, cacao, rubber, coffee, pineapples, coconut. We group these crops into two categories based on the purpose of production. The first category, food crops, include corn and rice, which are produced on a semi-subsistence basis by farmers for their own consumption and for sale to the market. The second category, cash crops, are crops for which production is undertaken on a commercial scale and its

[3]This survey provides rich data not only on production, but also on consumption and nutrition patterns of households, as the primary purpose of the survey was to study the effect of agricultural commercialization on nutrition.

primary purpose is to sell to the market and/or export. Among cash crops, the pre-dominant one in the study area is sugarcane and to a lesser extent coffee, coconut, and rubber. The dominance of sugarcane production as a cash crop was facilitated by the establishment of a sugar mill in the area named BUSCO, which provided farmers with the opportunity to switch from corn and rice to sugarcane production. In our sample there are farms that produce exclusively food crops, those that produce exclusively cash crops, and those that mix production between the two types.

We use our data to study the allocation of resources across cash and food crops at the farm level, and how the land reform affects that allocation. This crop mix decision at the farm level constitutes the "within" farm mechanism we emphasize.

To compare farm-level productivity across farms and across time (from 1984-85 to 2002-03) we use as constant prices for all farms the average 2002-03 crop and intermediate input prices to calculate value added. By fixing prices to their averages across farms in 2002-03, we are effectively purging the effect of price changes from changes in value added. Thus changes in value added reflect real changes. Productivity by farm in 1984-85 is calculated as the weighted average of productivities over the four rounds in that first wave of the survey. Similarly, productivity by farm in 2002-03 is calculated as the weighted average of productivities over the five seasons in this second wave of the survey.

In order to control for farmer ability and location we only focus on the farms that are present in both 1984-85 and 2002-03. This allows us to construct a two-year panel, with observations for the same set of farms in each year. There are 167 farms with productivity data in both years. We group the cash crop farms and mixed crop farms together because they are similar in their characteristics. Thus it should be clear that the category "cash crop" farms includes both those that produce only cash crops and those that produce cash crops and some food crops. The category "food crops" includes those that produce only food crops. Another categorization that we will emphasize is that between "small" - below 5 ha, and "large" - above 5 ha, where the cutoff of 5 ha is chosen to match

Table 2: Number of Farms By Crop and Size

	1984-85	2002-03
All Crops	167	167
< 5 Ha	130	141
5+ Ha	37	26
Cash Crops	103	123
< 5 Ha	71	99
5+ Ha	32	24
Food Crops	64	44
< 5 Ha	59	42
5+ Ha	5	2

the ceiling in the 1988 land reform. Table 2 reports the number of farms by crop and size in each of the two years of the panel.

There are two shifts that occurred over time that are apparent from this table. First, a shift from food crop farms to cash crop farms. Given that the set of farms is the same in each year, this indicates that some farmers switched from producing food crops to cash crops.[4] Second, there is a shift from large scale farms to small scale farms. This is true for both types of crops. Interestingly, the number of farms over 5 ha is not eliminated. This is consistent with the census data reported above. In sum, the share of cash crop farms increased from 62% in 1984-85 to 74% by 2002-03, while the share of small farms increased from 78% to 84% over the same period.

Table 3 displays average farm size and labor productivity by crop. Labor productivity is measured as value added at constant 2002-03 prices over the number of work days. The number of work days is a more precise measure of labor input as it counts how many full days are worked. This is one of the advantages of our data as it reports days worked by task on each of the farm's parcel.

[4] In 1984-85 the mixed crop farms are the biggest component of "cash crop" farms (97 out of 103). By 2002-03 mixed farms still remain the largest component of cash crop farms (76 of 123) but there is a major increase in the number of pure cash crop farms.

Table 3: Size and Productivity By Crop

	1984-85	2002-03	% change
All Farms			
Average Farm Size	3.7	3.1	-17.6
Value Added Per Work Day	257.5	372.7	44.7
Cash Crop Farms			
Average Farm Size	4.6	3.7	-19.8
Value Added Per Work Day	298.2	386.1	29.5
Food Crop Farms			
Average Farm Size	2.1	1.3	-39.0
Value Added Per Work Day	101.2	201.0	98.7

The number of work days is the total, which includes both family labor and hired labor. The first thing to notice from the table is that for all farms, average farm size dropped by 18% while labor productivity increased by 45%. This is consistent with the aggregate data reported earlier. Why this happens is not obvious at first sight since the tendancy is for average farm size to increase as productivity rises and labor moves out of agriculture. The other thing to note from the table is that in 1984-85 cash crop farms are on average larger (more than double in average farm size) and more productive (almost 3 times more) than food crop farms. Also, average farm size falls for both types of crops while labor productivity increases for both (although these effects are more pronounced for food crop farms).

The panel nature of our data allows us to observe which farms are the ones that changed their crop mix over the study period, and how did their farm size and productivity evolve over time. To do this we first construct a mobility matrix in Table 4. An entry in the mobility matrix indicates, given the crop farms were producing in 1984-85, what are they producing in 2002-03? The matrix shows that 83% of those farms producing cash crops in 1984-85 are still producing cash crops in 2002-03. From those producing food crops in 1984-85, 58% switched to cash crops by 2002-03, while much

Table 4: Crop Mobility Matrix

	2002-03	
1984-85	cash crops	food crops
cash crops	0.83	0.17
food crops	0.58	0.42

Table 5: Mobility Matrix - Size

	2002-03	
1984-85	cash cr.	food cr.
cash cr.	5.1	2.3
food cr.	2.5	1.6

AFS, 1984-85

	2002-03	
1984-85	cash cr.	food cr.
cash cr.	-16.5	-68.3
food cr.	-5.6	1.3

AFS, % change

less switching occurred the other way. So overall there was a shift of farmers towards cash cropping (as was seen with the summary statistics earlier).

In Tables 5 and 6 we examine what the levels and the changes in average farm size and productivity respectively, for each of the four entries in the crop mobility matrix. Of particular interest, are the characteristics of the farms that switched from food crops to cash crops. The tables indicate that, from the food crop farms in 1984-85, it was the largest in size and the most productive among food crop farms that switched to cash cropping by 2002-03. Also these switching farms are the ones that exhibited the strongest productivity growth among all farms over the time period (largely the effect of catch-up within the cash crop).

Table 6: Mobility Matrix - Productivity

	2002-03	
1984-85	cash cr.	food cr.
cash cr.	317.2	95.6
food cr.	107.8	85.1

VA per person day, 1984-85

	2002-03	
1984-85	cash cr.	food cr.
cash cr.	27.0	78.8
food cr.	162.2	150.5

VA per person day, % change

4 Model

We consider an industry model of agriculture and focus on the production side of the economy. In order to get a non-degenerate distribution of farm sizes, we embed a Lucas (1978) span-of-control model of firm size. In addition we allow operators to face a cropping technology choice (cash vs. food crop). The motivation for this technology choice is dictated by our data.

The production unit in agriculture is a farm that requires as inputs the managerial skills of a farm operator, the land input - which also defines the farm's size and hired labor. There are two technologies to produce agricultural goods: there are two types of goods/crops in the economy which we denote as cash c and food f crops. The production unit is a farm that requires the input of a farmer with individual productivity s, land l, and hired labor n according to a decreasing returns to scale technology:

$$y_i(s) = (A\kappa_i s)^{1-\gamma}(l^\alpha n^{1-\alpha})^\gamma,$$

for each crop $i \in \{c, f\}$. We denote the price of each crop by p_i. The rental prices of capital and hired labor are q and w.

The profit of the farmer with productivity s in each crop is given by

$$\pi_i(s) = \max\{p_i y_i - wn - ql - p_i C_i\}$$

where C_i is a fixed cost of operation in each crop in units of output of the crop. The first order conditions with respect to land and hired labor inputs are given by eqns 2 and 3 in notes. We note that these FOC'simply:

$$\frac{n}{l} = \frac{(1-\alpha)}{\alpha}\frac{q}{w},$$

It is optimal for farmers in both crops to choose the same hired labor - land ratio regardless of size. The input demand functions are the following:

$$l_i(s) = \left(\frac{\alpha}{q}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{\gamma(1-\alpha)}{1-\gamma}} (\gamma p_i)^{\frac{1}{1-\gamma}} A\kappa_i s,$$

$$l_i(s) = \left(\frac{\alpha}{q}\right)^{\frac{\gamma\alpha}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{1-\gamma\alpha}{1-\gamma}} (\gamma p_i)^{\frac{1}{1-\gamma}} A\kappa_i s,$$

Given these demands, $y_i(s)$ can be readily computed. Profits can be written as:

$$\pi_i(s) = (1-\gamma)p_i y_i(s) - p_i C_i.$$

Note that the input demand functions are linear in s and so is output. Then profits is an affine function of s. We can derive the optimal functions n, l, y, pi which are all afine functions of s. Thus, more able farmers operate larger farms, demand more labor, produce more output, and make more profits. Then for a given distribution of managerial ability the model implies a distribution of farm sizes.

The productivity of farmers is drown from a discrete set S according to a cdf $F(s)$ and pdf $f(s)$. Given that $\pi_i(s)$ is affine in s, there are two thresholds that determine the fraction of people being workers, cash crop farmers and food crop farmers. We denote the occupational choice by $o_i(s)$ with the convention that $o_i(s) = 1$ if $\pi_i \geq \max\{\pi_{-i}(s), w\}$ so an individual with ability s chooses to operate a farm in crop i and 0 otherwise. Then the clearing conditions are:

$$\sum_i \sum_s l_i(s) o_i(s) f(s) = L,$$

$$\sum_i \sum_s n_i(s) o_i(s) f(s) = N_w$$

where $N_w = \sum_i \sum_s (1 - o_i(s)) f(s)$ is the fraction of workers in the economy.

A competitive equilibrium is a set of prices (q, w), occupational decision rules $o_i(s)$, and farmers decision functions $n_i(s)$, $l_i(s)$, $\pi_i(s)$ such that: (i) Given prices, farmers optimize, (ii) Given prices, o_i are optimal occupational choice decisions, and (iii) markets clear.

For reasonable parameter values that are in line with the calibration ($\kappa_c > \kappa_f$ and $C_c > C_f$) the occupational choice and crop choice decisions of farmers are characterized by two thresholds $\underline{s}$ and $\overline{s}$, such that,

$$\pi_f(\underline{s}) = w$$

$$\pi_f(\overline{s}) = \pi_c(\overline{s})$$

Then those farmers with ability below $\underline{s}$ will become hired workers, those with ability between $\underline{s}$ and $\overline{s}$ will become food farm operators, and those with ability above $\overline{s}$ will become cash crop operators. So $\underline{s}$ determines the split between operators and farmers (occupational choice decision) and $\overline{s}$ determines the split between cash croppers and food croppers (crop technology choice).

4.1 Land Reform

We model land reform as a maximum land level l_{max} ceiling for farm size. In general, farm operation cannot exceed this level although in practice there are a few farms that do. This occurs mainly because there are informal arrangements among family members that permits ownership to abide by the reform while operation can remain above the threshold or simply because the implementation of the land redistribution takes time and is subject to enforcement problems. We model this aspect of the land reform as a probability θ that the operation can remain at the optimal level (dictated by the productivity of the farmer) while with probability $(1-\theta)$ operation is at the constrained level.

We define the indicator function $c_i(s)$ to take the value 1 if the optimal demand of the farmer is potentially constrained by the ceiling limit, i.e., $c_i(s) = 1$ if $l_i(s) \geq l_{max}$ and 0 otherwise. When a farmer is constrained, land size is l_{max} and hired labor is $n_{i,max}$ given implicitly by the first order condition for hired labor with $l_i = l_{max}$. We can write land and hired labor demand functions as ,

$$\hat{l}_i(s) = (1 - c_i(s))l_i(s) + c_i(s)[\theta l_i(s) + (1-\theta)l_{max}],$$

$$\hat{n}_i(s) = (1 - c_i(s))n_i(s) + c_i(s)[\theta n_i(s) + (1-\theta)n_{i,max}],$$

and profits are given by

$$\hat{\pi}_i(s) = (1 - c_i(s))\pi_i(s) + c_i(s)[\theta \pi_i(s) + (1-\theta)\pi_i^{l_{max}}(s)],$$

where $\pi_i^{l_{max}}(s)$ is the profit associated with the constraint $l = l_{max}$.

Then the occupational choice decisions are $\hat{o}_i(s) = 1$ if $\hat{\pi}_i(s) \geq \max\{\hat{\pi}_{-i}(s), w\}$ and 0 otherwise.

The market clearing conditions are then:

$$\sum_i \sum_s \hat{l}_i(s)\hat{o}_i(s)f(s) = L$$

$$\sum_i \sum_s \hat{n}_i(s)\hat{o}_i(s)f(s) = N_w$$

where N_w is the share of hired labor in the economy, i.e.,$N_w = \sum_i \sum_s (1 - \hat{o}_i(s))f(s)$.

Hence, land reform affects not only land demand directly, but indirectly affect hired labor, occupational choice decisions and demand functions of unconstrained farmers by general equilibrium effects.

5 Quantitative Analysis

5.1 Calibration

We calibrate a benchmark economy without any restriction on farm size to pre-reform Philippines, using the survey data. The parameters to be calibrated are: technological parameters $\{A, \kappa_c, \kappa_f, \alpha, \gamma, \{s\}\}$, distributional parameters, and the land endowment L. Some parameter values are chosen based on a priori information, while others are solved for as part of the solution to the model's equilibrium in order to match targets in the data.

We choose the distribution of farmer ability to match the distribution of farm sizes in the survey data (panel) in 1984-85. The distribution of farmer ability is approximated by a log-normal distribution with mean μ and variance σ^2. We approximate the set of farmer abilities with a linearly spaced grid of 6000 points in $[s_{min}, s_{max}]$, with s_{min} close to 0 and s_{max} equal to 15 which ensures a maximum sized farm of 23 hectares, the largest farm in our panel in 1984-85. 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 the food crop-specific productivity κ_f to 1 for the benchmark economy. Given that the two crop prices are exogenous in our formulation we normalize the relative price of cash crops to food crops to unity. We set the span-of-control parameter to 0.7 and then choose α to match a land income share of 20%. The aggregate land endowment is chosen to match an average farm size of 3.7 hectares (panel data for 1984-85). We then choose the remaining parameters - the two fixed operating costs (C_f, C_c) and the cash crop TFP κ_c - to match three data targets: (1) a share of hired labor in total farm labor of 61.1%; (2) a share of cash crop operators in total operators of 61.7%; (3) a ratio of average output per worker between cash crops and food crops of 2.95. The model parameters along with their targets and calibrated values are provided in Table 7.

Table 7: Parameterization

Parameter	Value	Target
Technological Parameters		
A	1	Normalization
κ_f	1	Normalization
p_c/p_f	1	Normalization
γ	0.7	span-of-control
α	0.3	land income share
κ_c	1.21	Ratio of average crop productivities
C_f	-0.56751	Share of hired labor in total farm labor
C_c	-0.51119	Share of cash crop operators in total operators
Parameters of Ability Distribution		
μ	-0.85714	Size distribution
σ	1.25	Size distribution
Land Endowment		
L	1.4393	Average farm size

The calibrated model does well in matching the farm size distribution by choice of the parameters of the ability distribution (see Figure 4). While not calibrated to do so the model matches well the distribution of land, e.g. it reproduces the observation that about 45% of the land is in farms of less than 5 ha (see Figure 5).

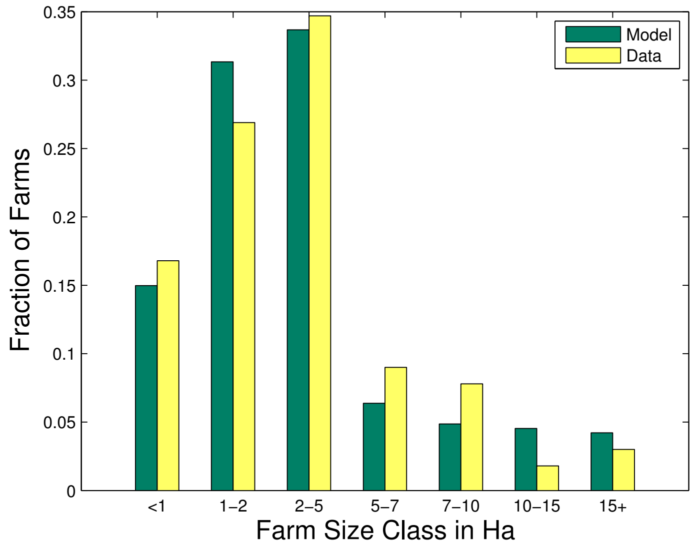

Figure 4: Share of Farms by Size

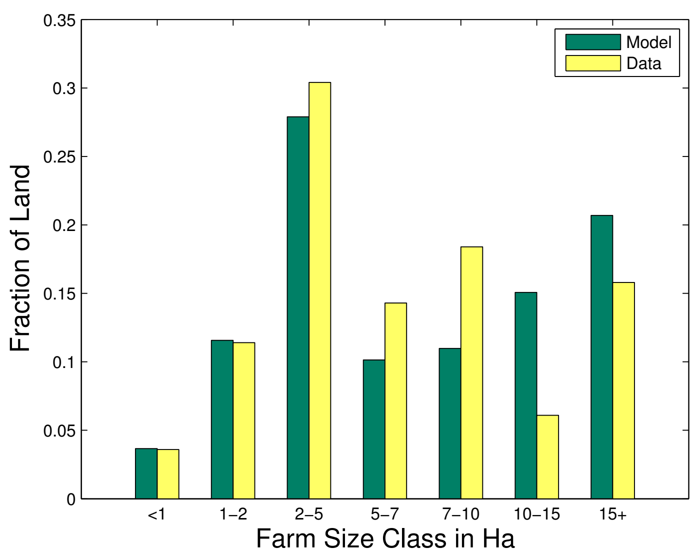

Figure 5: Share of Land in Farms by Size

Table 8: Changes in Farm Size and Productivity

	Enforcement			
	$\theta = 1$	$\theta = 0.5$	$\theta = 0.2$	$\theta = 0$
Average Farm Size (%Δ)	0	-3.6	-6.6	-9.3
Output Per Worker (%Δ)	0	-1.9	-3.5	-5.0

5.2 Results

The main quantitative experiment we conduct is the following: we take the benchmark economy calibrated to pre-reform Philippines, and consider the land reform variant of the model of Section 4.1, feeding in the legislated ceiling of 5 hectares. In Table 8 we show the effect of the land reform on farm size and productivity for different levels of enforcement θ. The results indicate that the land reform leads to a drop in both labor productivity and average farm size. Further, the drops in productivity and average farm size are larger the greater the degree of enforcement (lower θ). A value of $\theta = 1$ means that the reform is not enforced at all, so there is no change in average farm size or productivity. A value of $\theta = 0$ means that the land reform is fully enforced so the effects are the strongest: a 5% drop in productivity and a 9.3% drop in average farm size. In the data 16% of farms are more than 5 hectares. The θ that guarantees this share is around 0.01 (closer to 0 in other words).

Next, we study in more detail what causes the drop in productivity in the model by examining the effect of the reform on productivity growth by crop and the occupational choice allocation. We focus on the case of full enforcement of the land reform. The results are presented in Table 9.

The intuition behind the main mechanism of the model is the following. The land reform by imposing a ceiling on land holdings reduces the farm size for all farmers s that had a farm operation

Table 9: Effects of Land Reform ($\theta = 0$)

%Δ in aggregate output per worker	-5.0
%Δ in cash crop output per worker	-6.9
%Δ in food crop output per worker	3.3
Δ in hired labor (%)	- 1.0
Δ in cash crop operators (%)	5.0
Δ in food crop operators (%)	-4.0

above the ceiling (direct effect) - these are the constrained farmers. This causes an oversupply of land in the land market reducing the price of land q. For a given occupational allocation between hired workers - operators and food crop operators - cash crop operators, the decline in farm size for the constrained operators implies a decline in the demand for labor for the constrained operators, given the hired labor is proportional to farm size. This tends to reduce the overall demand for labor in the market, which tends to reduce the wage rate w.

The decrease in the wage rate and the rental price of land means that factor inputs are now cheaper, which increases the demand for hired labor and land by the unconstrained operators (general equilibrium effect). The misallocation effect of the land reform on productivity is the reallocation of farming activity from larger more productive operators to smaller less productive operators. In other words, the land reform distorts size by inefficiently "propping up" previously small farms and restricting efficient large farms - so that less able operators become artificially large. This reduces both farm size and productivity. For a given allocation of hired workers-operators (i.e., given $\underline{s}$) the decrease in w and q increase the profits for all food crop farmers (see profits in equilibrium) while reducing w. This means that there will be an increase in the number of operators and a decrease in the number of hired workers. In other words, as $\underline{s}$ falls some farmers switch from hired workers to operators. Note, that the generated increase in the demand for hired labor tends to increase w.

For a given allocation of food crop operators - cash crop operators (i.e. for a given $\overline{s}$) and for given decreases in w, q profits will increase for both food crop farmers and cash crop farmers but will increase more so for cash crop farmers because $\kappa_c > \kappa_f$. That is, there is a switch of operators to the higher productivity crop, so you get more operators flowing to cash crops. These changes in the occupational allocation and crop choice of farmers impart a selection effect on productivity. The decrease in $\underline{s}$ means that you get more low ability operators in food crops. The decrease in $\overline{s}$ means that the more able food crop farmers are switching to cash crops. These effects will both tend to dampen productivity in food crops. But these food crop farmers are the ones that are less likely to be constrained. So because of the general equilibrium effect of the decrease in w and q they hire more and produce more. Here this positive productivity effect dominates the effect of the selection effect and food crop farming productivity increases in equilibrium. The decline in $\overline{s}$ means that you have more low ability operators entering cash cropping. This selection effect tends to dampen productivity. Plus, these operators are the ones being hit by the ceiling. Combined these effects reduce productivity in cash crops. The overall effect on selection depends on these changes as well as output shares (plus some other minor terms). Given that cash crops have the highest output share, quantitatively the selection in cash cropping dominates leading to a fall in productivity. So here both the selection and reallocation effects reduce productivity. However, selection could in principle go the other way if the food crops' effect dominated (i.e., if they had the higher output share).

We also decompose the overall effect on productivity into the reallocation and misallocation effects. The counterfactual experiment we run is the following: what would be the effect on productivity if we precluded the occupational allocation to change but still required the land and labor markets to clear - that is, if reallocation was the only channel through which productivity was changing. The

Table 10: Productivity Decomposition

Total Effect (%Δ)	-5.0
Misallocation Effect (%Δ)	-3.0
Selection Effect (%Δ)	-2.0

Table 11: Effect of Additional Factors

	Land Reform	+ increase in A
% Δ in Average Farm Size	-9.3	26.4
% Δ in Output Per worker	-5.0	5.6

results of this experiment are reported in Table 10. We find this way that the reallocation channel accounts for 60% of the overall productivity growth.

Next, we feed in a 15% increase in economy-wide TFP A (to match the increase in non-agricultural labor productivity), in addition to the land reform. The second column of Table 11 shows that the increase in A along side the reform results in an increase in farm size and productivity. In other words, other changes can mask the negative effects of the reform on size and productivity.

In this sense, it is useful to look at the land reform through the lens of the model, because it allows you to disentangle the impact of the land reform from other factors.

References

Adamopoulos, T., and D. Restuccia (forthcoming), "The Size Distribution of Farms and International Productivity Differences," *American Economic Review.*

Banerjee, A. V. (1999), "Prospects and Strategies for Land Reforms," in B. Pleskovic and J. Stiglitz (eds), *Annual World Bank Conference on Development Economics 1999*, Washington, DC, World Bank, 253-84.

Besley, T., and R. Burgess (2000),"Land Reform, Poverty Reduction, and Growth: Evidence from India," *Quarterly Journal of Economics*, 389-430.

Borras, S.M. (2003), "Inclusion-Exclusion in Public Policies and Policy Analyses: The Case of Philippine Land Reform, 1972-2002," *Journal of International Development* 15, 1049-1065.

Bouis, H.E., and L.J. Haddad (1990), *Agricultural Commercialization, Nutrition, and the Rural Poor: A Study of Philippine Farm Households,* Boulder, Colorado, U.S.A: Lynne Rienner.

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

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.