

Agricultural Composition, Structural Change and Labor Productivity *

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Abstract

The differences in labor productivity between developed and developing countries are substantially larger in agriculture than in non-agriculture. We argue that structural change within agricultural sectors explains part of these differences. We consider two agricultural sectors that are differentiated only by the capital intensity of the production function. As capital accumulates, the price of the non-capital intensive agricultural sector relative to the price of the capital intensive agricultural sector increases. This price change drives a process of structural change within agriculture that depends on the value of the elasticity of substitution among agricultural goods. When this elasticity is large, we show that this structural change driven by capital accumulation implies (i) a reduction in the number of farmers; (ii) an increase in the average farm size; (iii) an increase in the capital intensity of the agricultural sector relative to the non-agricultural sector; and (iv) an increase in the labor productivity of the agricultural sector relative to the non-agricultural sector. We highlight that if the elasticity is low then the sectoral composition within the agricultural sector remains constant, which implies that capital intensity does not increase, the increase in the average farm size is small and, hence, the increase in the labor productivity of the agricultural sector is also small. We conclude that structural change within agriculture contributes to explain the fast increase in agricultural productivity.

JEL classification codes: O41, O47.

Keywords: structural change, agriculture labor productivity, capital intensity.

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1 Introduction

A recent strand of the growth literature argues that a substantial part of cross-country income differences can be explained by differences in agricultural labor productivity between developing and developed countries.¹ In particular, Lagakos and Waugh (2013) report that agricultural labor productivity in countries in the 90th percentile of the world income distribution is 45 times larger than that of countries in the 10th percentile of the distribution. In contrast, non-agricultural labor productivity is only 4 times larger in advanced countries. Since agricultural employment shares are high in developing countries, this literature concludes that cross-country income differences are, in part, the result of low labor productivity in this sector.

To account for differences in labor productivity between agriculture and non-agriculture in developing countries, the literature has focused on misallocations introduced by institutions (Chen (2016), Gottlieb and Grobovsek (2015), Hayashi and Prescott (2008), Restuccia et al. (2008), Restuccia and Santaella-Llopis (2017)), differences in farm sizes (Adamopoulos and Restuccia (2014)), selection (Lagakos and Waugh (2013)), differences in technology (Chen (2017), Gollin et al. (2007), Yang and Zhu (2013)), uninsurable risk and incomplete capital markets (Donovan (2016)), and differences in vintage capital (Caunedo and Keller (2016)).

The aforementioned literature considers an aggregate agricultural sector producing a single commodity. It disregards the fact that agricultural products are diverse, that they can be produced with different technologies and that consumption of these products can change as the economy develops. The purpose of this paper is to identify a process of structural change within the agricultural sector associated to economic development and to study how changes in the composition of this sector contribute to explain observed differences in agricultural labor productivity and income levels across countries.

We use crop level data, available at the US Census of Agriculture, to distinguish between two different agricultural sectors differentiated by the capital intensity of the technology: a capital intensive and a land intensive sectors.² Since the Census provides capital usage at crop level, we can identify directly which crops are produced with the capital intensive technology. To this end, we compute for each crop the ratio between capital and value of production. We can then distinguish between two groups of crops. Those crops that under the North American Industry Classification System (NAICS) are identified as oilseed and grain farming, and other crop farming have a ratio of capital to production close or above one. We denote this group of crops as capital intensive. Those other crops identified as vegetable and melon farming, and fruit and tree nut farming have a ratio around 0.33. We denote this group of crops as non-capital intensive or land intensive. Note that the differences in capital intensity between the groups are large and, moreover, we use census data since 1978 to show that the differences are stable through time.³ In Table 1, we summarize the resulting classification of crops.

Using this classification and the Food and Agriculture Organization (FAO) dataset, we can compute production, prices and arable land for each agricultural sector. Figure 1 indicates that the relative price between land and capital intensive sectors increases, whereas the relative production between these two sectors declines. This evidence suggests imperfect substitution in consumption

¹See Chanda and Dalgaard (2008), Cao and Birchenall (2013), Gollin et al. (2002), Gollin et al. (2013) and Gollin and Rogerson (2014), Restuccia et al. (2008) and Vollrath (2009).

²The data only distinguishes sectors by capital intensity. In the model, we show that the low capital intensive sector is, in fact, the land intensive sector. Accordingly, we denote the sectors as land and capital intensive.

³We use census data from the years 1978, 1982, 1987, 1992, 1997, 2002, and 2012. Although the first 4 census use the Standard Industrial Classification system (SIC), we can still identify the same groups of crops to conclude that the differences in capital intensity between the two groups of crops remain constant and large.

between agricultural goods.

As a framework of analysis, we use an overlapping generations (OLG) model where a continuum of individuals is born in each period. These individuals have heterogeneous abilities in farming. As in Lucas (1978), young individuals with low abilities choose to be workers, whereas individuals with high ability become entrepreneurs. In our framework, workers are employed in non-agriculture, while entrepreneurs are farmers specialized in the production of either land or capital intensive crops. Since technologies exhibit complementarity between ability and capital, only farmers endowed with high abilities choose to produce capital intensive crops.

When old, individuals consume non-agricultural products and an agricultural product that is subject to a minimum consumption requirement. The agricultural good is a constant elasticity of substitution (CES) aggregate of capital and land intensive crops. Consistent with the data shown in Figure 1, we assume that the elasticity of substitution between these crops is larger than one.

Economic growth is due to capital accumulation and it causes two different processes of structural change: between sectors and within the agricultural sector. First, the minimum consumption requirement introduces an income effect that reduces the relative size of the agricultural sector and the number of farms as a result of an income increase. The remaining farmers have larger abilities and larger farms. This is consistent with evidence provided by Adamopoulos and Restuccia (2014) who report that the average farm size in low income countries is 50 times smaller than farm sizes in high income countries. This process of structural change implies that agricultural productivity increases with economic development as a consequence of both selection and farm size. This mechanism explaining that agricultural productivity increases was already introduced by Lagakos and Waugh (2013).

Second, as capital becomes more abundant, the relative price of land to capital intensive crops increases, which is consistent with the evolution of prices in Figure 1. Given imperfect substitution between these goods, the relative production of land to capital intensive crops declines. As a consequence, agriculture becomes more capital intensive and labor in this sector more productive. In sum, in this paper we propose increasing capital intensity in agriculture as another driving mechanism behind observed differences in agricultural productivity between developed and developing countries. The increase in capital intensity in agriculture relative to non-agriculture, along the process of economic development, is consistent with evidence provided by Chen (2016) and Alvarez-Cuadrado et al. (2013). In particular, Chen (2016) indicates that the capital-output ratio in agriculture is 3.2 times larger in developed countries than in developing countries, and only 2.1 times larger in non-agriculture.

This paper is closely related to Alvarez-Cuadrado et al. (2013), Chen (2017) and Gollin et al. (2007). In these papers, economic growth is associated to a more capital intensive technology in the agricultural sector. In Alvarez-Cuadrado et al. (2013) this process is the consequence of a CES production function in the agricultural sector, with a large substitutability between capital and labor. On the other hand, Chen (2017) and Gollin et al. (2007) introduce a process of technological change in agriculture, from land to capital intensive technology. In contrast to these authors, in this paper the increase in capital intensity is not the consequence of technological change, but it is the result of substitution among crops and, hence, it depends on the value of the elasticity of substitution among these crops.

We simulate the model and show that the transitional dynamics it generates is consistent with the following facts associated to economic development: (i) a reduction in the employment share in agriculture, (ii) an increase in the average farm size, (iii) an increase in the capital-output ratio in agriculture relative to non-agriculture, and (iv) an increase in the productivity of agriculture relative to non-agriculture. Note that the later fact implies that agricultural productivity differences between developing and developed countries are larger than the productivity differences in the

non-agricultural sector. In the numerical exercises we emphasize the importance of the elasticity of substitution. We find that low elasticity of substitution limits the process of structural change within agriculture and, as a consequence, the increase of labor productivity in this sector.

Finally, we study the effects of two different types of market inefficiencies. First, we assume an extreme labor mobility barrier that fixes the shares of non-agricultural workers and of land and capital intensive farmers. We use this extreme misallocation to show that, absent structural change, the model is unable to account for rising agricultural productivity relative to non-agriculture productivity. Second, we assume larger borrowing costs in agriculture than in non-agriculture. We show that this capital inefficiency, specific to agriculture, reduces labor productivity mainly at the start of the transition, when capital is scarce and the country has low income. As a consequence, this inefficiency contributes to explain the large agricultural productivity differences between developing and developed countries.

The rest of the paper is organized as follows. Section 2 introduces the model and Section 3 characterizes the equilibrium. Section 4 solves numerically the model and obtains the main results. Finally, Section 5 includes some concluding remarks.

2 Model

2.1 Individuals

The economy is populated by a continuum of individuals of mass one. Individuals live for two periods. When young, they work and save. When old, they consume the accumulated savings. Individuals are different regarding their abilities to be farmers. We denote the ability as a farmer of an individual by $a^i \in [a_{min}, a_{max}]$. These abilities follow a truncated Pareto distribution with density function $f(a^i) = \lambda a_{min}^\lambda (a^i)^{-(1+\lambda)} / (1 - a_{min}^\lambda a_{max}^{-\lambda})$ and cumulative function $F(a^i) = (1 - a_{min}^\lambda (a^i)^{-\lambda}) / (1 - a_{min}^\lambda a_{max}^{-\lambda})$. In addition, we assume that all individuals have the same ability as workers in non-agriculture.

An individual i derives utility from consumption in the second period of his life according to

$$U_t^i = \omega \ln(c_{a,t+1}^i - \bar{c}) + (1 - \omega) \ln c_{n,t+1}^i, \quad (1)$$

where $c_{a,t+1}^i$ is the consumption of agricultural goods, $c_{n,t+1}^i$ is the consumption of non-agricultural goods, $\bar{c}$ is a subsistence level of agricultural consumption, and $\omega \in (0, 1)$ is the weight of agricultural consumption in the utility function. The agricultural good is an aggregate of goods produced with either a capital or a land intensive technology. We assume that these goods are imperfect substitutes. Therefore, $c_{a,t+1}^i$ is defined as

$$c_a^i = \left[\mu (c_L^i)^{\frac{\varepsilon-1}{\varepsilon}} + (1 - \mu) (c_K^i)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (2)$$

where $\mu \in (0, 1)$ is the weight of land intensive goods, and $\varepsilon > 0$ is the elasticity of substitution between land intensive goods, c_L^i , and capital intensive goods, c_K^i .

Let total consumption expenditure be

$$E_{t+1}^i \equiv P_{n,t+1} c_{n,t+1}^i + P_{L,t+1} c_{L,t+1}^i + P_{K,t+1} c_{K,t+1}^i, \quad (3)$$

where $P_{L,t+1}$ is the price of the land intensive goods, $P_{K,t+1}$ is the price of the capital intensive goods and $P_{n,t+1} = 1$ for all t , as the output of the non-agricultural sector is assumed to be the

numeraire. The following individuals' consumption demands are obtained from maximizing utility subject to (3):⁴

$$c_{L,t+1}^i = \omega \mu^\varepsilon \left(\frac{P_{L,t+1}}{P_{a,t+1}} \right)^{1-\varepsilon} \frac{E_{t+1}^i}{P_{L,t+1}} + (1-\omega) \mu^\varepsilon \left(\frac{P_{L,t+1}}{P_{a,t+1}} \right)^{-\varepsilon} \bar{c}, \quad (4)$$

$$c_{K,t+1}^i = \omega (1-\mu)^\varepsilon \left(\frac{P_{K,t+1}}{P_{a,t+1}} \right)^{1-\varepsilon} \frac{E_{t+1}^i}{P_{K,t+1}} + (1-\omega) (1-\mu)^\varepsilon \left(\frac{P_{K,t+1}}{P_{a,t+1}} \right)^{-\varepsilon} \bar{c}, \quad (5)$$

$$c_{n,t+1}^i = (1-\omega) E_{t+1}^i - (1-\omega) P_{a,t+1} \bar{c}, \quad (6)$$

where

$$P_{a,t+1} \equiv \left(\mu^\varepsilon P_{L,t+1}^{1-\varepsilon} + (1-\mu)^\varepsilon P_{K,t+1}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}. \quad (7)$$

2.2 Technology

We distinguish between three production sectors: two agricultural and one non-agricultural. Firms in non-agriculture produce combining capital and labor according to the following constant returns to scale production function

$$Y_{n,t} = A_n K_{n,t}^{\alpha_n} N_{n,t}^{1-\alpha_n}, \quad (8)$$

where $Y_{n,t}$ is output in non-agriculture, A_n is a productivity parameter, $K_{n,t}$ is the capital stock employed in this sector, $N_{n,t}$ is the total amount of labor employed in this sector and $\alpha_n \in (0, 1)$ is the capital-output elasticity. We assume that capital completely depreciates after one period. We also assume perfect competition and, hence, the wage and the rental price of capital satisfy

$$w_t = (1 - \alpha_n) A_n K_{n,t}^{\alpha_n} N_{n,t}^{-\alpha_n},$$

and

$$R_t = \alpha_n A_n K_{n,t}^{\alpha_n-1} N_{n,t}^{1-\alpha_n}. \quad (9)$$

As capital completely depreciates, the rental price of capital satisfies $R_t = 1 + r_t$, where r_t is the interest rate. Note that the output of this sector is the numeraire of the economy. Finally, it will be useful for our analysis to obtain the following relationship

$$w_t = \alpha_n^{\frac{\alpha_n}{1-\alpha_n}} (1 - \alpha_n) A_n^{\frac{1}{1-\alpha_n}} R_t^{\frac{\alpha_n}{\alpha_n-1}} \quad (10)$$

Individuals working in agriculture are the owners of the farm. Farmers can produce either land or a capital intensive crops. Land intensive farms produce according to the following technology

$$y_{L,t}^i = A_L a^i (L_{L,t}^i)^{\beta_L}, \quad (11)$$

where $y_{L,t}^i$ is the output produced by a farmer with ability a^i in the land intensive sector, A_L is the productivity parameter, $L_{L,t}^i$ is the amount of land that a farmer with ability a^i buys and $\beta_L \in (0, 1)$ measures the decreasing returns to land. In order to buy land, the young farmer borrows from the credit market. When old, the farmer pays the credit and the interest rate, $\tilde{r}_t$. We assume that financial markets are not perfect in agriculture and, hence, there is a financial inefficiency that we denote by $\tau > 1$. It follows that $\tilde{r}_t = \tau r_t$ and

$$\tilde{R}_t \equiv 1 + \tilde{r}_t = \tau R_t + (1 - \tau). \quad (12)$$

⁴See appendix A.1 for details on the derivation of consumption demands.

Note that $\tilde{R}_t > R_t$ implies that the cost of the credit is larger than the rental price of capital. Finally, when old, farmers sell the land. Hence, the profit of a land intensive farm that produces in period t and sells the land in period $t + 1$ is

$$\pi_{L,t}^i = P_{L,t} y_{L,t}^i - (\tilde{R}_t P_t - P_{t+1}) L_{L,t}^i,$$

where $P_{L,t}$ is the price of the land intensive agricultural product and P_t is the price of land.

Farmers choose land to maximize $\pi_{L,t}^i$. It follows that the demand of land is

$$L_{L,t}^i = \left(\frac{\beta_L P_{L,t} A_L a^i}{x_t} \right)^{\frac{1}{1-\beta_L}}, \quad (13)$$

where

$$x_t = \tilde{R}_t P_t - P_{t+1} \quad (14)$$

is the rental cost of one unit of land. Note that the size of a land intensive farm, measured by $L_{L,t}^i$, increases with farmer's ability, but decreases with the cost of land. Note also that this cost increases with the financial inefficiency, reducing farm sizes. Finally, we replace (13) in the profit function to obtain

$$\pi_{L,t}^i(a^i) = (1 - \beta_L) \left[\left(\frac{\beta_L}{x_t} \right)^{\beta_L} P_{L,t} A_L a^i \right]^{\frac{1}{1-\beta_L}}. \quad (15)$$

Capital intensive farms produce using capital and land according to the following production function

$$y_{K,t}^i = A_K a^i (L_{K,t}^i)^{\beta_K} (K_{K,t}^i)^{\alpha_K}, \quad (16)$$

where $y_{K,t}^i$ is the agricultural output produced by a farmer with ability a^i in the capital intensive sector, A_K is productivity parameter, $L_{K,t}^i$ and $K_{K,t}^i$ are, respectively, the amount of land and capital used in production and $\beta_K \in (0, 1)$ and $\alpha_K \in (0, 1)$ measure, respectively, the land and capital to output elasticities. We assume that $\beta_K + \alpha_K < 1$ and, hence, the production function exhibits decreasing returns to scale.

Farmers in the capital intensive sector borrow from the markets to buy capital and land. These farmers bear the financial inefficiency, implying that when old they must pay the cost $\tilde{R}_t$ for the credit obtained when young. At this point, it is important to clarify that the financial inefficiency is specific of the agricultural sector, which can be explained by higher monitoring costs. Finally, when old, farmers sell the land but not the capital, as it completely depreciates after one period. It follows that the profit of a capital intensive farm is

$$\pi_{K,t}^i = P_{K,t} y_{K,t}^i - x_t L_{K,t}^i - \tilde{R}_t K_{K,t}^i,$$

where $P_{K,t}$ is the price of capital intensive agricultural output.

Farmers choose land and capital to maximize $\pi_{K,t}^i$. From the first order conditions, we obtain that the demands of capital and land are, respectively,

$$K_{K,t}^i = \left[\left(\frac{\alpha_K}{\tilde{R}_t} \right)^{1-\beta_K} \left(\frac{\beta_K}{x_t} \right)^{\beta_K} P_{K,t} A_K a^i \right]^{\frac{1}{1-\beta_K-\alpha_K}}, \quad (17)$$

$$L_{K,t}^i = \left[\left(\frac{\alpha_K}{\tilde{R}_t} \right)^{\alpha_K} \left(\frac{\beta_K}{x_t} \right)^{1-\alpha_K} P_{K,t} A_K a^i \right]^{\frac{1}{1-\beta_K-\alpha_K}}. \quad (18)$$

Optimal profits are given by

$$\pi_{K,t}^i(a^i) = (1 - \beta_K - \alpha_K) \left[\left(\frac{\alpha_K}{\tilde{R}_t} \right)^{\alpha_K} \left(\frac{\beta_K}{x_t} \right)^{\beta_K} P_{K,t} A_K a^i \right]^{\frac{1}{1 - \beta_K - \alpha_K}}. \quad (19)$$

Note that the optimal size of the capital intensive farm, given by (18), increases with ability and decreases with both the cost of land and the financial inefficiency.

2.3 Individuals' decisions

Young individuals decide the sector where they work. Obviously, this decision depends on their abilities. To understand this decision, we derive the ability of the marginal individual, indifferent between working in non-agriculture and in the land intensive agricultural sector. Let us denote by $\underline{a}_t$ the ability of this marginal individual. Then, individuals with an ability lower than $\underline{a}_t$ will prefer to work in non-agriculture. This ability is obtained from solving the following equation: $\pi_{L,t}^i(\underline{a}_t) = (1 - \phi) w_t$, where $\phi \in (0, 1)$ is a labor income tax. Using (10) and (13), we find that

$$\underline{a}_t = \left(\frac{(1 - \phi) \alpha_n^{\frac{\alpha_n}{1 - \alpha_n}} (1 - \alpha_n) A_n^{\frac{1}{1 - \alpha_n}} R_t^{\frac{\alpha_n}{\alpha_n - 1}}}{(1 - \beta_L) P_{L,t} A_L} \right)^{1 - \beta_L} \left(\frac{x_t}{\beta_L P_{L,t} A_L} \right)^{\beta_L}. \quad (20)$$

We denote by $\bar{a}_t$ the ability of the marginal individual that is indifferent between being a farmer in the land or in the capital intensive sector. This ability is obtained from solving the following equation: $\pi_{L,t}^i(\bar{a}_t) = \pi_{K,t}^i(\bar{a}_t)$. From using (13), (17) and (18), we obtain

$$\bar{a}_t = \left[\frac{\left(\frac{\alpha_K}{\beta_K} \right)^{\alpha_K} \left(\frac{(1 - \beta_K - \alpha_K) P_{K,t} A_K}{(1 - \beta_L) P_{L,t} A_L} \right)^{1 - \beta_K - \alpha_K} \left(\frac{\beta_K P_{K,t} A_K}{\tilde{R}_t} \right)^{\alpha_K + \beta_K}}{\left(\frac{\tilde{R}_t}{x_t} \right)^{\beta_K} \left(\frac{x_t}{\beta_L P_{L,t} A_L} \right)^{\frac{\beta_L (1 - \beta_K - \alpha_K)}{1 - \beta_L}}} \right]^{\frac{1 - \beta_L}{\beta_L - \beta_K - \alpha_K}} \quad (21)$$

If $\beta_L < \beta_K + \alpha_K$, individuals with ability above $\bar{a}_t$ will be farmers of a capital intensive farm, whereas individuals with ability below $\bar{a}_t$ will be either farmers in land intensive agriculture or workers in the non-agricultural sector.⁵ More precisely, under appropriate parameter constraints, we have that $\bar{a}_t > \underline{a}_t$ and, hence, individuals with $a^i \in [a_{min}, \underline{a}_t]$ will be workers in the non-agricultural sector, individuals with $a^i \in [\underline{a}_t, \bar{a}_t]$ will be farmers in the land intensive sector and individuals with $a^i \in [\bar{a}_t, a_{max}]$ will be farmers in the capital intensive sector. From now on, we assume that $\beta_L < \beta_K + \alpha_K$ and $\bar{a}_t > \underline{a}_t$ so that the aforementioned characterization of individual occupational decisions holds.

The condition $\beta_L \leq \beta_K / (1 - \alpha_K)$ implies that the size of the farm of the marginal individual is larger if he decides to be a farmer in the capital intensive sector, that is $L_{L,t}^i(\bar{a}_t) \leq L_{K,t}^i(\bar{a}_t)$. Hence, when farmers shift to the capital intensive sector the size of the average farm increases. In fact, when the inequality $\beta_L < \beta_K / (1 - \alpha_K)$ is strict, the distribution of land sizes will not be continuous as there is a gap between $L_{L,t}^i(\bar{a}_t)$ and $L_{K,t}^i(\bar{a}_t)$. To avoid this undesired feature, we assume that $\beta_L = \beta_K / (1 - \alpha_K)$.⁶

The previous assumption implies that the value of production of the marginal individual satisfies $P_L y_{L,t}^i(\bar{a}_t) < P_K y_{K,t}^i(\bar{a}_t)$. In turn, this implies an output gain when an extra farmer shifts to the

⁵This result follows from using (15) and (19) and taking into account that $\pi_{L,t}(\bar{a}_t) = \pi_{K,t}(\bar{a}_t)$.

⁶To show this result, it is enough to realize that $L_{L,t}^i / \pi_{L,t}^i = \beta_L / (x_t (1 - \beta_L))$ and that $L_{K,t}^i / \pi_{K,t}^i = \beta_K / (x_t (1 - \beta_K - \alpha_K))$. As $\pi_{L,t}^i(\bar{a}) = \pi_{K,t}^i(\bar{a})$ then $L_{L,t}^i(\bar{a}) \leq L_{K,t}^i(\bar{a})$ if and only if $\beta_L \leq \beta_K / (1 - \alpha_K)$.

capital intensive sector. This production increase is generated by a productivity gain. In order to see this, we use (11), (13), (16), and (18) to show that

$$\frac{P_{L,t} y_{L,t}^i}{L_{L,t}^i} = \frac{x_t}{\beta_L}, \quad (22)$$

and

$$\frac{P_{K,t} y_{K,t}^i}{L_{K,t}^i} = \frac{x_t}{\beta_K}. \quad (23)$$

As $\beta_L > \beta_K$, the production per unit of land is clearly larger in the capital intensive farms.

3 Equilibrium

Individuals consume when old the income they generate when young. The consumption expenditure of an old individual that was a non-agricultural worker in period t is $E_{t+1}^{n,i} = R_{t+1} (1 - \phi) w_t$. The expenditure of an old individual that was a land intensive farmer is $E_{t+1}^{L,i} = R_{t+1} \pi_{L,t}^i (a^i)$. Similarly, the expenditure of an old individual that was a capital intensive farmer is $E_{t+1}^{K,i} = R_{t+1} \pi_{K,t}^i (a^i)$. Finally, we assume that tax revenues are returned to individuals.⁷ Hence, aggregate consumption expenditure is given by⁸

$$E_{t+1} = \int_{a_{min}}^{a_t} \left(E_{t+1}^{n,i} + \phi R_{t+1} w_t \right) f(a^i) di + \int_{a_t}^{\bar{a}_t} E_{t+1}^{L,i} f(a^i) di + \int_{\bar{a}_t}^{a_{max}} E_{t+1}^{K,i} f(a^i) di. \quad (24)$$

Using (4), (5) and (6), we obtain aggregate consumption of land and capital intensive agricultural products, and aggregate consumption of non-agricultural products that, respectively, are given by

$$C_{L,t+1} = \omega \mu^\varepsilon \left(\frac{P_{L,t+1}}{P_{a,t+1}} \right)^{1-\varepsilon} \frac{E_{t+1}}{P_{L,t+1}} + (1 - \omega) \mu^\varepsilon \left(\frac{P_{a,t+1}}{P_{L,t+1}} \right)^\varepsilon \bar{c}, \quad (25)$$

$$C_{K,t+1} = \omega (1 - \mu)^\varepsilon \left(\frac{P_{K,t+1}}{P_{a,t+1}} \right)^{1-\varepsilon} \frac{E_{t+1}}{P_{K,t+1}} + (1 - \omega) (1 - \mu)^\varepsilon \left(\frac{P_{a,t+1}}{P_{K,t+1}} \right)^\varepsilon \bar{c}, \quad (26)$$

$$C_{n,t+1} = (1 - \omega) E_{t+1} - (1 - \omega) P_{a,t+1} \bar{c}. \quad (27)$$

The aggregate demands of land and capital in each sector and the aggregate productions are used to characterize the equilibrium of this economy. In order to obtain the aggregate demand of land in the land and capital intensive agricultural sectors, we use (13) and (18) to obtain

$$L_{L,t} = \int_{a_t}^{\bar{a}_t} L_{L,t}^i f(a^i) di = \left(\frac{\beta_L P_{L,t} A_L}{x_t} \right)^{\frac{1}{1-\beta_L}} \Delta_{L,t}, \quad (28)$$

and

$$L_{K,t} = \int_{\bar{a}_t}^{a_{max}} L_{K,t}^i f(a^i) di = \left[\left(\frac{\alpha_K}{\bar{R}_t} \right)^{\alpha_K} \left(\frac{\beta_K}{x_t} \right)^{1-\alpha_K} P_{K,t} A_K \right]^{\frac{1}{1-\beta_K-\alpha_K}} \Delta_{K,t}, \quad (29)$$

where $\Delta_{L,t}$ and $\Delta_{K,t}$ are defined in Appendix A.2.

⁷ Given that preferences belong to the Gorman class of preferences, the distribution of tax revenues among individuals does not affect aggregate demand.

⁸ Appendix A.2 provides an analytical expression of aggregate expenditure.

To obtain the aggregate demand of capital in capital intensive agriculture and in non-agriculture, we use (17) and (9) to obtain

$$K_{K,t} = \int_{\bar{a}_t}^{a_{max}} K_{K,t}^i f(a^i) di = \left[\left(\frac{\alpha_K}{\tilde{R}_t} \right)^{1-\beta_K} \left(\frac{\beta_K}{x_t} \right)^{\beta_K} P_{K,t} A_K \right]^{\frac{1}{1-\beta_K-\alpha_K}} \Delta_{K,t}, \quad (30)$$

and

$$K_{n,t} = \left(\frac{\alpha_n A_n}{R_t} \right)^{\frac{1}{1-\alpha_n}} N_{n,t}, \quad (31)$$

where the amount of workers in the non-agricultural sector is $N_n = F(\underline{a}) = (1 - a_{min}^\lambda \underline{a}^{-\lambda}) / (1 - a_{min}^\lambda a_{max}^{-\lambda})$. We define by K_t the total stock of capital that satisfies

$$K_t = K_{n,t} + K_{K,t}. \quad (32)$$

Finally, we use (11) and (16) to obtain the aggregate production of land and capital intensive agricultural goods

$$Y_{L,t} = \int_{\underline{a}_t}^{\bar{a}_t} y_{L,t}^i f(a^i) di = A_L \left(\frac{\beta_L P_{L,t} A_L}{x_t} \right)^{\frac{\beta_L}{1-\beta_L}} \Delta_{L,t}, \quad (33)$$

and

$$Y_{K,t} = \int_{\bar{a}_t}^{a_{max}} y_{K,t}^i f(a^i) di = A_K \left[\left(\frac{\alpha_K}{\tilde{R}_t} \right)^{\alpha_K} \left(\frac{\beta_K}{x_t} \right)^{\beta_K} (P_{K,t} A_K)^{\alpha_K + \beta_K} \right]^{\frac{1}{1-\beta_K-\alpha_K}} \Delta_{K,t}. \quad (34)$$

Before defining the equilibrium, we must take into account that the financial inefficiency introduces a cost, interpreted as a monitoring cost, that enters into the resource constraint of the non-agricultural sector. This financial cost is given by $\Omega_t = (\tau - 1) r_t (P_t L + K_{K,t})$.

Given K_0 , an equilibrium of this economy is a path of ability thresholds $\{\underline{a}_t, \bar{a}_t\}_{t=0}^\infty$ that satisfies (20) and (21), a path of aggregate demands of land $\{L_{L,t}, L_{K,t}\}_{t=0}^\infty$ that satisfies (28) and (29), a path of aggregate demands of capital $\{K_{n,t}, K_{K,t}\}_{t=0}^\infty$ that satisfies (30) and (31), a path of aggregate consumption demands $\{C_{n,t}, C_{K,t}, C_{L,t}\}_{t=0}^\infty$ that satisfies (25), (26) and (27), a path of sectoral outputs $\{Y_{n,t}, Y_{K,t}, Y_{L,t}\}_{t=0}^\infty$ that satisfies (8), (33) and (34), a path of aggregate consumption expenditure and capital $\{E_t, K_t\}_{t=0}^\infty$ that satisfies (24) and (32), **and** a path of prices $\{P_{a,t}, \tilde{R}_t, R_t, P_{L,t}, P_{K,t}, x_t\}_{t=0}^\infty$ that satisfies (7) and (12), and market clearing conditions for land intensive agricultural goods, $C_{L,t} = Y_{L,t}$, for capital intensive agricultural goods, $C_{K,t} = Y_{K,t}$, for non-agricultural products, $Y_{n,t} = C_{n,t} + K_{t+1} + \Omega_t$, and for land holdings $L = L_{L,t} + L_{K,t}$, where L is the fixed amount of total agricultural land.

4 Numerical simulations

4.1 Calibration

As a first step, we use data from FAO for the U.S. economy and compute the value of production, the share of land and the price index (base year 2014) for both agricultural sectors. Figure 1 summarizes the data. As observed in the figure, the relative price of land to capital intensive

agricultural goods increases, while the share of land allocated in land intensive agriculture declines. This implies that the agricultural goods are substitutes in consumption.⁹

The value of production in 2014 and the price indexes are also used to calibrate the parameters of the production functions. Valentinyi and Herrendorf (2008) provide capital and land income shares in agriculture and in non-agriculture for the U.S. economy. We use these shares and the relation $\beta_L = \beta_K / (1 - \alpha_K)$ to obtain the values for α_n , α_K , β_K and β_L . In particular, the capital and land income shares in agriculture satisfy the following equations

$$\beta_L \frac{P_L Y_L}{P_K Y_K + P_L Y_L} + \beta_K \frac{P_K Y_K}{P_K Y_K + P_L Y_L} = 0.18,$$

and

$$\alpha_K \frac{P_K Y_K}{P_K Y_K + P_L Y_L} = 0.36,$$

where $P_L Y_L / (P_K Y_K + P_L Y_L)$ is the fraction of agricultural value added generated in the land intensive sector in 2014, the land income share in agriculture equals 0.18 and the capital income share in agriculture equals 0.36.

On the other hand, the productivity parameters of the different sectors are set as follows: A_n is normalized to one, A_L is set to match the value of the ratio between the two price indexes in 2014, which is equal to one, and A_K is set to a value such that the labor productivity in agriculture equals the labor productivity in non-agriculture in steady state.

Regarding the preference parameters, ω is set so that the long-run share of employment in the agricultural sector equals 1%, μ is set to match the fraction of agricultural value added generated in the capital intensive sector in 2014, and $\bar{c}$ is set to match the fraction of employment in the agricultural sector in 2014.

The parameters characterizing the distribution of abilities are set to match the distribution of farms sizes reported by Adamopoulos and Restuccia (2014). In particular, we normalize a_{min} to one and we set a_{max} to match the range of farm sizes in the U.S. Finally, λ is set so that 38% of farms are small (less than 50 hectares).

Finally, we set $\tau = 1$ which implies no financial inefficiency. The parameter values and the targets of calibration are summarized in Table 2.

4.2 Structural change and labor productivity

Figure 2 shows the transitional dynamics of the benchmark economy from an initially low capital stock level.¹⁰ Therefore, capital accumulation drives economic growth in this economy. Panel (a) shows the process of structural change out of agriculture. This is driven by an income effect, resulting from the minimum consumption requirements. Taking into account that a period is about 20 years, the first three periods of the simulation match the structural transformation exhibited by the U.S. economy during the period 1961-2014.

The reduction of the agricultural employment share implies an increase in average farm sizes. This is shown in Panel (b), where the average farm size is decomposed between the average farms sizes of the two agricultural sectors. The panel shows large differences in average farm size between agricultural sectors, and that the fast increase in the average farm size is mostly explained by the shift of farmers to the capital intensive sector. This process of structural change within agriculture

⁹Using (22) and (23), we obtain that $P_L c_L / P_K c_K = (\beta_K / \beta_L) (L_L / L_K)$. Thus, there is a direct relationship between the sectoral composition in terms of value added and in terms of land.

¹⁰We assume that the initial capital stock is 20% of its steady state level. This implies that if capital grows at a 2% annual growth rate, the economy will be close to its steady state after 4 periods (80 years).

is shown in Panels (c), (d) and (f). Panel (c) displays the reduction in the land share used in land intensive agriculture. From the comparison to Figure 1, we can conclude that the model can explain most of the reduction. Panel (d) shows the process of structural change within agriculture in terms of labor, while Panel (f) in terms of production.

The process of structural change between the two agricultural sectors is due to the increase in the relative price illustrated in Panel (e). The simulation is consistent with the long-run evolution of the prices in the data. The rise in the relative price is explained in the model by capital accumulation along the transition, that benefits the capital intensive agricultural sector.

The aforementioned process of structural change explains the increase in capital intensity in agriculture relative to non-agriculture. This is shown in Panel (g). The relative capital intensity between the capital intensive agricultural sector and non-agriculture (continuous line) is constant and slightly above one. The relative capital intensity between total agriculture and non-agriculture (dashed line) exhibits an increasing pattern. To account for this pattern, we introduce the following decomposition

$$\frac{K_{K,t}/(P_{K,t}Y_{K,t} + P_{L,t}Y_{L,t})}{K_{n,t}/Y_{n,t}} = \frac{R_t}{\widetilde{R}_t} \left(\frac{P_{K,t}Y_{K,t}}{P_{K,t}Y_{K,t} + P_{L,t}Y_{L,t}} \right) \frac{\alpha_K}{\alpha_n}, \quad (35)$$

where we make use of equations (9), (30) and (34). Note that relative capital intensity depends on three components: the inefficiency in the capital market, the sectoral composition within the agricultural sector and the capital output elasticities. In the absence of inefficiencies, as it is assumed in the benchmark simulation, and without production in land intensive agriculture the capital intensity would be constant and equal to $\alpha_K/\alpha_n = 1.41$. Therefore, the increase in the capital intensity shown in Panel (g) is the result of the process of structural change within the agriculture, where the fraction of the value added generated by the capital intensive sector increases.

The last panel in Figure 2 shows the increase of labor productivity in agricultural sector relative to non-agriculture. This pattern is the consequence of three forces: selection, the increase in the average farm size and the increase of the capital intensity in agriculture. This pattern implies that along the development process the labor productivity grows faster in agriculture.

In sum, the benchmark economy illustrated in Figure 2 is consistent with the following development facts: (i) a reduction in the employment share in agriculture, (ii) an increase in the average farm size, (iii) an increase in the capital intensity in agriculture relative to non-agriculture, and (iv) an increase in relative labor productivity in agriculture.

At this point, it is important to clarify that our contribution is to distinguish between the two agricultural sectors. If we had assumed a single agricultural sector, the model would not explain the increase in relative capital intensity and would imply a substantially smaller increase in farm sizes. As a consequence, the model would fail to generate a sufficient increase in agricultural labor productivity. In fact, labor productivity in agriculture relative to non-agriculture would decline in the absence of structural change within agriculture. To clarify this point, we illustrate in Panel (h) relative labor productivities in the land and in the capital intensive sectors. As observed in this panel, relative labor productivity declines in capital intensive agriculture and it is flat in land intensive agriculture. Therefore, the rising relative labor productivity shown in Panel (i) results from farmers moving to the more productive sector.

The aforementioned mechanism of structural change crucially depends on the elasticity of substitution between agricultural goods. Figure 3 shows the simulation of three economies that differ in the value of this elasticity. We illustrate the following cases: the benchmark economy, where goods are imperfect substitutes ($\varepsilon = 10$), an economy with strong substitution ($\varepsilon = 100$), and an economy where goods are complementary ($\varepsilon = 0.9$). As expected, Panel (e) shows that the relative price increases in the three economies. Panel (g) shows the evolution of the ratio between the value

of production. This ratio increases when goods are complementaries and declines when they are substitutes. From the comparison to Figure 1, we find that the elasticity of substitution consistent with the data is such that $\varepsilon = 10$.

The fraction of land and of farmers in the agricultural land intensive sector is larger when the elasticity of substitution is small (see Panels (c) and (d) of Figure 3). As the productivity of this sector is smaller, a low value of the elasticity of substitution implies that the total number of farmers is larger (Panel (a)) and the average farm size is smaller (Panel (b)). In other words, a low elasticity of substitution limits structural change within agriculture. In fact, Panel (c) shows that if goods are complements the fraction of land in the land intensive sector remains almost constant. This explains why the relative capital intensity in agriculture is both smaller and constant through the transition when the elasticity is low.

Finally, Panel (i) shows that relative labor productivity in agriculture is smaller and grows less when the elasticity of substitution is low. This results from smaller average farm sizes and lower relative capital intensity. We conclude that the value of the elasticity of substitution, by shaping the process of structural change within agriculture, is crucial to explain the increase in labor productivity in agriculture relative to non-agriculture.

Thus far, low agricultural labor productivity is explained by low capital stock in developing countries. This is in contrast to a large part of the literature that argues in favor of a misallocation of resources to explain low productivity. Following this literature, we introduce inefficiencies in the next section.

4.3 Misallocation

In this section, we consider the effects of two inefficiencies: an extreme labor mobility barrier and an imperfection in the capital market. The former implies fixed shares of individuals working in non-agriculture and in land intensive farms. In other words, N_a , N_K and N_L remain constant. The dashed lines in Figure 4 display the transitional dynamics for this economy, while the continuous lines the simulation for the benchmark economy. This figure allows us to study how structural change affects labor productivity in agriculture.

Panel (i) shows that the ratio of labor productivity between agriculture and non-agriculture declines when barriers to labor mobility limit structural change. On the one hand, average farm size remains constant when N_a is fixed and, hence, it does not contribute to increase labor productivity (see Panel (b)). On the other hand, since the fraction of capital intensive farms is fixed, capital intensity in agriculture is near constant (flat dashed line in Panel (h)). Both effects limit the growth of labor productivity in agriculture. Finally, Panel (g) shows large differences in output across economies, that provide a measure of output loss due to this misallocation.

The second source of inefficiency introduced in this section are differences in the cost of borrowing between agriculture and non-agriculture. Banerjee (2001), Banerjee and Duflo (2005), Banerjee and Moll (2010) and Karlan (2013) provide evidence showing that borrowing interest rates are larger in developing countries, specially in agriculture. In Figure 5 we show how inefficiencies in capital markets in agriculture affect sectoral composition and labor productivity in this sector. The continuous lines in Figure 5 show the simulation of an economy without financial inefficiencies, $\tau = 1$. The dashed lines show the simulation results for an economy with $\tau = 1.5$.

The inefficiency causes an initial large decline in total consumption expenditures (see Panel (f)). The income effect, resulting from non-homothetic preferences, increases the number of farmers in the economy with $\tau = 1.5$ and, hence, the average farm size is initially smaller. The inefficiency implies $R/R < 1$ which, according to (35), reduces capital intensity in agriculture relative to non-agriculture, as shown in Panel (h). Both effects explain the initially smaller relative labor

productivity.

As capital accumulates, the relative labor productivity in agriculture grows faster in the economy with $\tau = 1.5$. This is explained by the changes in both relative capital intensity and in average farm size. On one hand, as capital accumulates, the interest rates declines and the ratio $R/\bar{R}$ increases. The evolution of this ratio explains the fast increase of capital intensity in the economy with $\tau = 1.5$. On the other hand, the financial cost increases the demand of non-agricultural goods. As a consequence, the price of this sector increases leading low ability farmers to non-agriculture. This effect dominates the labor market decisions when the income effect is sufficiently small. As economic development reduces the income effect, eventually the number of farmers becomes smaller in the economy with $\tau = 1.5$, which explains a larger average farm size. Clearly, both the evolution of farm size and of capital intensity explains why the relative labor productivity in the economy with $\tau = 1.5$ is larger later in the transition. Finally, Panels (f) and (g) show that, although output is larger in the economy with $\tau = 1.5$, total consumption expenditures are lower.

We emphasize that the increase in the relative labor productivity is larger when $\tau = 1.5$. Therefore, in line with previous findings in the literature, the misallocation contributes to explain differences in agricultural labor productivity between countries of different income levels. We conclude that the financial inefficiency and the process of structural change within agriculture provide complementary explanations for labor productivity differences in agriculture.

5 Concluding remarks

The literature reports that differences in labor productivity between developed and developing countries are substantially larger in agriculture than in non-agriculture. Since agricultural employment is large in developing countries, explaining these large differences in agricultural productivity is central to understand cross-country income differences. In this paper, we argue that the sectoral composition within agriculture can explain part of the low agricultural productivity observed in the developing countries.

We consider two agricultural sectors that differ only in the degree of capital intensity in production. As capital becomes abundant, the price of the land intensive sector relative the capital intensive sector increases. This relative price change drives a process of structural change within agriculture that depends on the value of the elasticity of substitution between agricultural goods. When this elasticity is larger than one, we show that structural change, driven by capital accumulation, implies (i) a reduction in the number of farmers, mainly in the land intensive sector, (ii) an increase in the average farm size, and (iii) an increase in the capital intensity of the agricultural sector relative to non-agriculture. Higher average farm size and agricultural capital intensity lead to higher labor productivity in agriculture.

When the two agricultural goods are complements in preferences, we find that labor productivity gains in agriculture are substantially lower. In this case, the sectoral composition within agriculture remains constant, which implies that capital intensity does not increase and that the increase in average farm size is small. We conclude that the elasticity of substitution drives structural change within agriculture and is a key determinant of agricultural productivity.

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Appendix A.1: Consumers' problem

In this appendix we derive the solution to the consumer problem, summarized in equations (4), (5) and (6). The consumer chooses c_L, c_K and c_n to maximize (1) subject to (2) and (3). We break the problem in two steps.

First, consumers choose c_L^i and c_K^i to maximize (2) subject to

$$E_{a,t+1}^i = P_{L,t+1} c_{L,t+1}^i + P_{K,t+1} c_{K,t+1}^i,$$

where $E_{a,t+1}^i$ is the agricultural expenditure of individual i . Maximization implies

$$c_{L,t+1}^i = \mu^\varepsilon \left(\frac{P_{L,t+1}}{P_{a,t+1}} \right)^{1-\varepsilon} \frac{E_{a,t+1}^i}{P_{L,t+1}}, \quad (36)$$

$$c_{K,t+1}^i = (1-\mu)^\varepsilon \left(\frac{P_{K,t+1}}{P_{a,t+1}} \right)^{1-\varepsilon} \frac{E_{a,t+1}^i}{P_{K,t+1}}, \quad (37)$$

where

$$P_{a,t+1} \equiv [\mu^\varepsilon P_{L,t+1}^{1-\varepsilon} + (1-\mu)^\varepsilon P_{K,t+1}^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}}.$$

Note that this price satisfies

$$P_{a,t+1} c_{a,t+1}^i = E_{a,t+1}^i \equiv P_{L,t+1} c_{L,t+1}^i + P_{K,t+1} c_{K,t+1}^i.$$

Second, consumers choose c_a^i and c_n^i by maximizing (1) subject to

$$E_{t+1}^i = c_{n,t+1}^i + P_{a,t+1} c_{a,t+1}^i.$$

Maximization implies equation (6) and

$$P_{a,t+1} c_{a,t+1}^i = \omega E_{t+1}^i + (1-\omega) P_{a,t+1} \bar{c}.$$

Combining this last equation with (36) and (37), we can obtain equations (4) and (5).

Appendix A.2: Aggregate consumption expenditures

Using (24), we obtain aggregate consumption expenditure as

$$\begin{aligned} E_t &= R_t w_{t-1} \int_{a_{\min}}^{a_{t-1}} f(a^i) di + R_t \int_{\underline{a}_{t-1}}^{\bar{a}_{t-1}} \pi_{L,t-1}^i(a^i) f(a^i) di + \\ &R_t \int_{\bar{a}_{t-1}}^{a_{\max}} \pi_{K,t-1}^i(a^i) f(a^i) di. \end{aligned} \quad (38)$$

We next use (10), (15) and (19), to obtain

$$\begin{aligned} E_t &= R_t \alpha_n^{\frac{\alpha_n}{1-\alpha_n}} (1-\alpha_n) A_n^{\frac{1}{1-\alpha_n}} R_{t-1}^{\frac{\alpha_n}{1-\alpha_n}} \frac{1 - a_{\min}^\lambda (\underline{a}_t)^{-\lambda}}{\left(1 - a_{\min}^\lambda a_{\max}^{-\lambda}\right)} + \\ &R_t (1-\beta_L) \left[\left(\frac{\beta_L}{x_{t-1}} \right)^{\beta_L} P_{L,t-1} A_L \right]^{\frac{1}{1-\beta_L}} \Delta_{L,t-1} + \\ &R_t (1-\beta_K - \alpha_K) \left[\left(\frac{\alpha_K}{\widetilde{R}_{t-1}} \right)^{\alpha_K} \left(\frac{\beta_K}{x_{t-1}} \right)^{\beta_K} P_{K,t-1} A_K \right]^{\frac{1}{1-\beta_K - \alpha_K}} \Delta_{K,t-1}, \end{aligned}$$

where

$$\Delta_{L,t} = \left(\frac{\lambda a_{\min}^{\lambda}}{1 - a_{\min}^{\lambda} a_{\max}^{-\lambda}} \right) \left(\frac{(\bar{a}_t)^{\frac{1}{1-\beta_L}-\lambda} - (\underline{a}_t)^{\frac{1}{1-\beta_L}-\lambda}}{\frac{1}{1-\beta_L} - \lambda} \right),$$

$$\Delta_{K,t} = \frac{\lambda a_{\min}^{\lambda}}{1 - a_{\min}^{\lambda} a_{\max}^{-\lambda}} \left(\frac{(a_{\max})^{\frac{1}{1-\beta_K-\alpha_K}-\lambda} - (\bar{a}_t)^{\frac{1}{1-\beta_K-\alpha_K}-\lambda}}{\frac{1}{1-\beta_K-\alpha_K} - \lambda} \right).$$

Appendix: Tables and figures

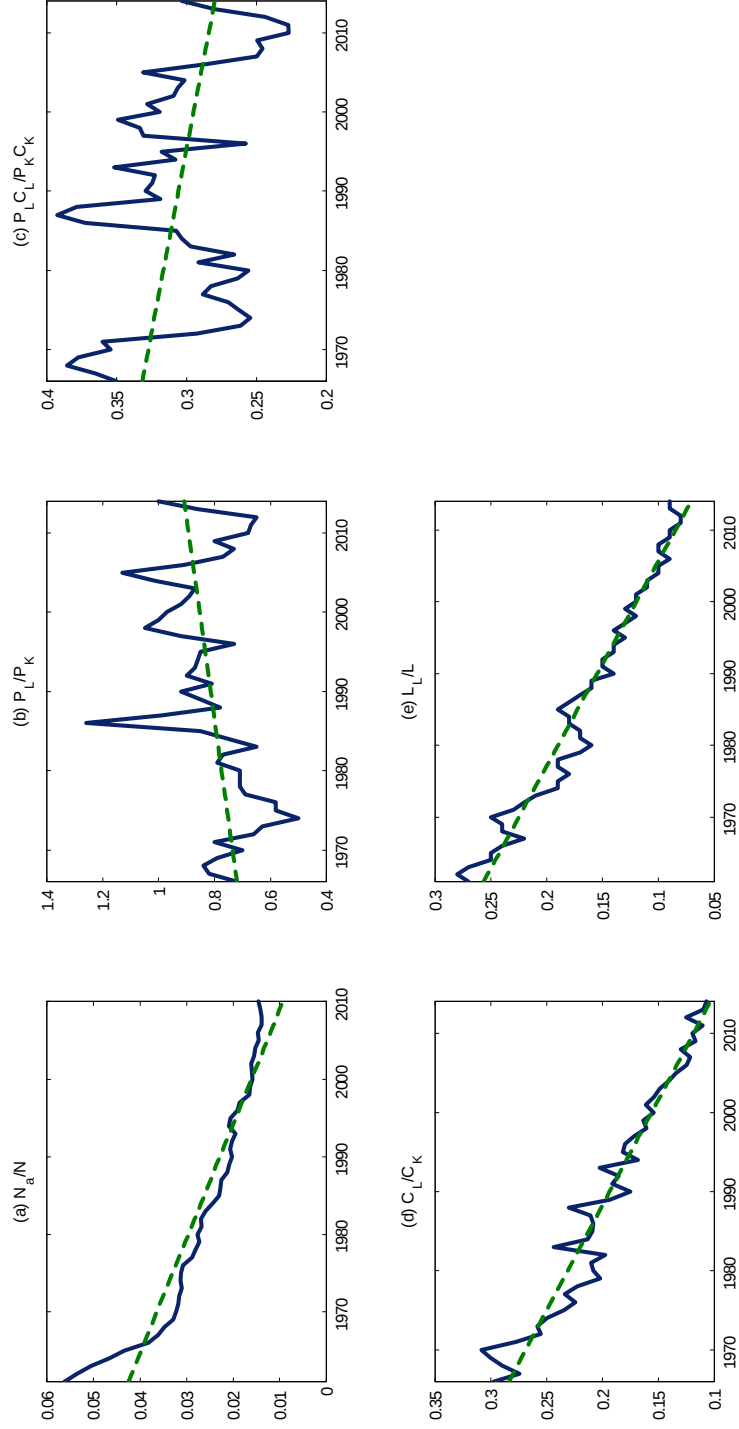
Table 1: Classification of crops

Land Intensive crops:
Berry (except strawberry) farming (111334), tree nut farming (111335), apple orchards (111331), potato farming (111211), other noncitrus fruit farming (111339), other vegetable (except potato) and melon farming (111219), grape vineyards (111332), orange groves (11131), citrus (except orange) groves (11132), fruit and tree nut combination farming (111336), strawberry farming (111333).
Capital intensive crops:
Sugarcane farming (11193), cotton farming (11192), rice farming (11116), corn farming (11115), dry pea and bean farming (11113), tobacco farming (11191), soybean farming (11111), other grain farming (11119), oilseed (except soybean) farming (11112), wheat farming (11114), all other crop farming (11199).

Table 2: Calibration

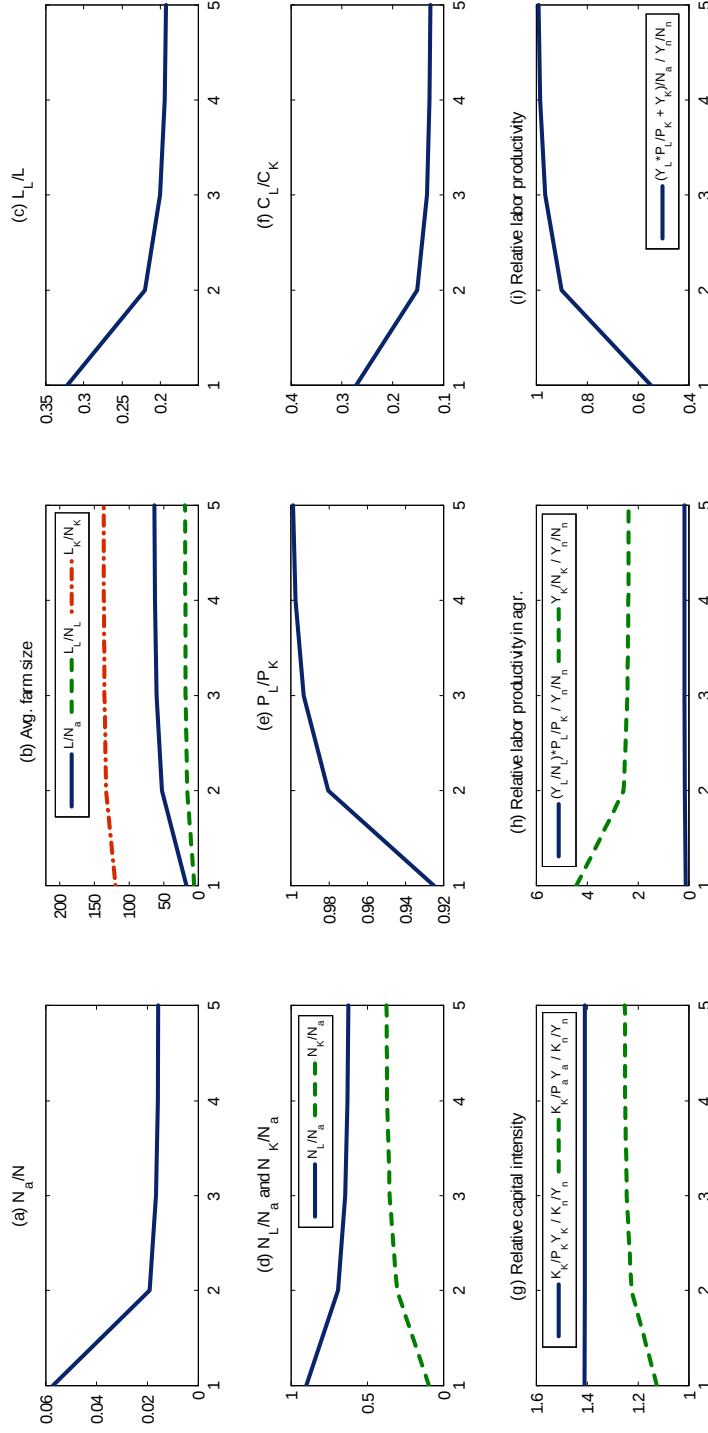
Parameter	Value	Target
ω	0.01	Long-run employment share in agriculture
$\bar{c}$	0.0044	Employment share in agriculture in U.S. in 2014 (1.5%)
μ	0.4482	$P_L Y_L / (P_L Y_L + P_K Y_K) = 0.23$ in U.S. in 2014
ϵ	10	Land share in land intensive agr. in U.S. in 1961 (28%)
A_n	1	Normalization
A_L	0.17	$P_L / P_K = 1$ in 2014
A_K	0.446	$(Y_L(P_L/P_K) + Y_K)/N_a/Y_n/N_n = 1$ in 2014
α_n	0.33	Valentinyi and Herrendorf (2008)
β_L	0.283	$\beta_L = \beta_K(1 - \alpha_K)$
β_K	0.15	$\beta_L(P_L Y_L)/(P_L Y_L + P_K Y_K) + \beta_K(P_K Y_K)/(P_L Y_L + P_K Y_K) = 0.18$
α_K	0.47	$\alpha_K(P_K Y_K)/(P_L Y_L + P_K Y_K) = 0.36$
λ	0.751	Distribution of farm size in U.S. in 2007 (38% of farms with less than 50 ha).
$a_{\min}$	0.001	Range of farm sizes between 1 and 2000 ha.
$a_{\max}$	1	Normalization
τ	1	Developed economy
L	1	Normalization

Figure 1



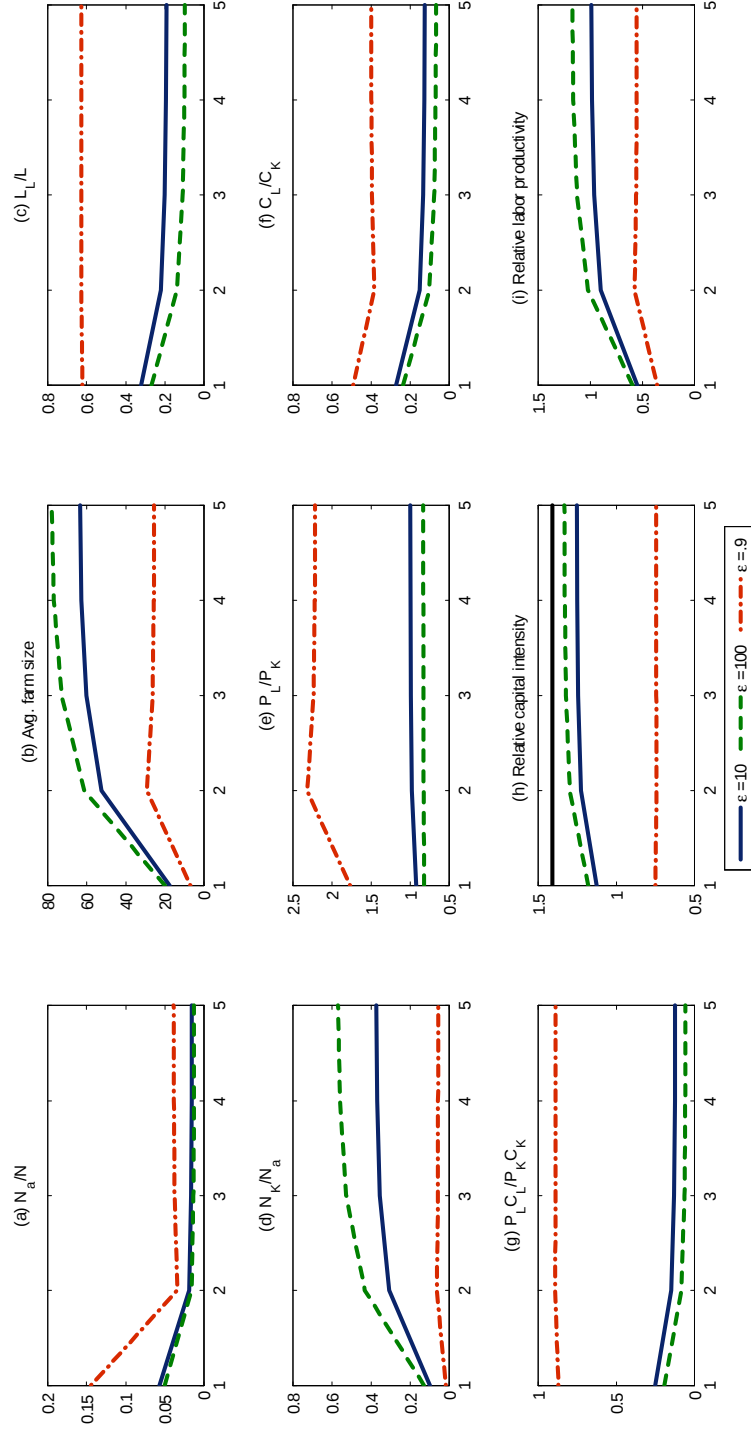
We use data available at FAO. The continuous line indicates observed data, the dashed line is a linear trend. The variables N_a/N , P_L/P_K , $P_L C_L/P_K C_K$, C_L/C_K and L_L/L indicate employment share in agriculture, relative price of land intensive to capital intensive agricultural goods, ratio of expenditure in land intensive agricultural goods to capital intensive agricultural goods, ratio of land intensive agricultural real output to capital intensive real output, and land share in land intensive crops, respectively.

Figure 2



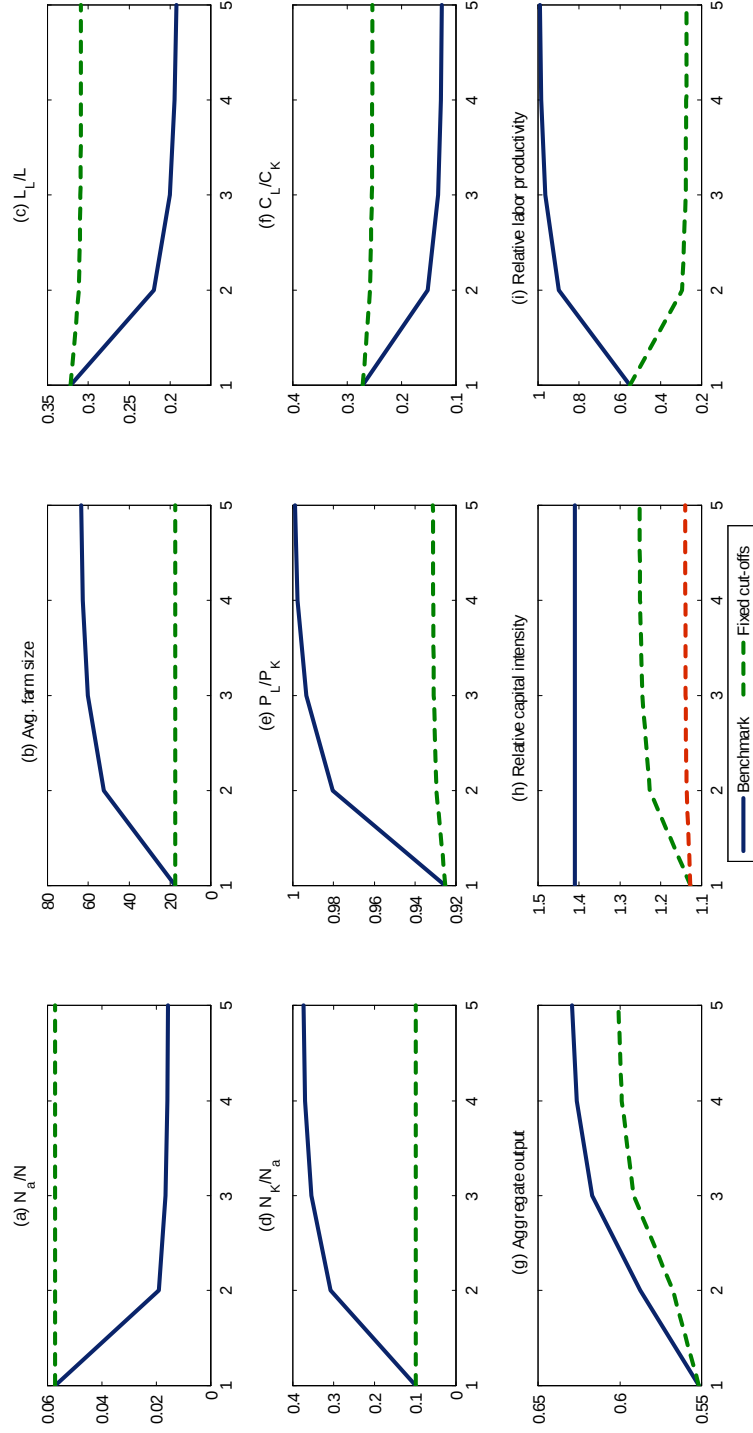
Panel (a) shows employment share in agriculture. Panel (b) average farm size (continuous line), avg. farm size in the land intensive sector (dashed line) and in the capital intensive sector (dashed and dotted line). Panel (c) land share in land intensive sector. Panel (d) shows agricultural employment in land intensive sector (continuous line) and in the capital intensive sector (dashed line). Panel (e) the relative price. Panel (f) relative real output. Panel (g) the relative capital intensity in capital intensive agriculture (continuous line) and in total agriculture (dashed line). Panel (h) relative real agricultural productivity in capital intensive agriculture (dashed line) and in land intensive agriculture (continuous line). Panel (i) the relative real labor productivity.

Figure 3



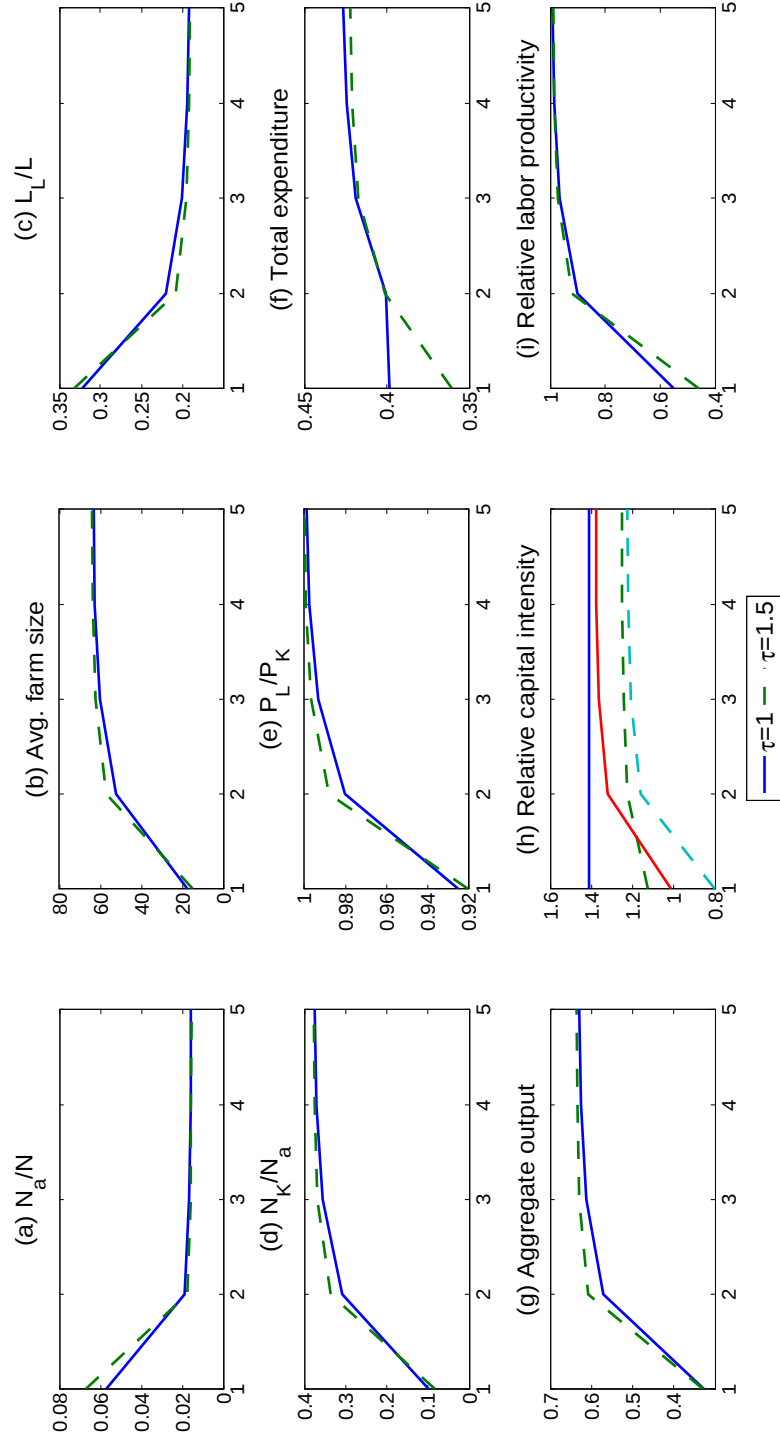
The continuous line indicates $\varepsilon = 10$, the dashed line $\varepsilon = 100$ and the dotted line $\varepsilon = 0.9$. Panel (a) shows employment share in agriculture. Panel (b) average farm size. Panel (c) land share in the land intensive sector. Panel (d) agricultural employment in capital intensive sector. Panel (e) the relative price. Panel (f) relative real output. Panel (g) the relative expenditure. Panel (h) relative capital intensity in capital intensive agriculture (horizontal line) and relative capital intensity in total agriculture. Panel (i) the relative real labor productivity.

Figure 4



The continuous line shows the benchmark simulation, the dashed line the simulation with mobility barriers. Panel (a) shows employment share in agriculture. Panel (b) average farm size. Panel (c) land share in the land intensive sector. Panel (d) agricultural employment in capital intensive sector. Panel (e) the relative price. Panel (f) relative real output. Panel (g) aggregate output. Panel (h) relative capital intensity in capital intensive agriculture (continuous horizontal line), in total agriculture with fixed cut-offs (horizontal dashed line) and in total agriculture without fixed cut-offs (increasing dashed line). Panel (i) the relative real labor productivity.

Figure 5



The continuous line indicates $\tau = 1$, the dashed line $\tau = 1.5$. Panel (a) shows employment share in agriculture. Panel (b) average farm size. Panel (c) land share in the land intensive sector. Panel (d) agricultural employment in capital intensive sector. Panel (e) the relative price. Panel (f) total expenditure. Panel (g) aggregate output. Panel (h) relative capital intensity in capital intensive agriculture (continuous line) and in total agriculture (dashed line). Panel (i) the relative real labor productivity.