Agricultural Productivity Differences and Credit Market Imperfections

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Abstract

This paper presents a simple model to examine the implication of credit market imperfections when considering the massive variation of agricultural labor productivity across countries. The development of credit markets enables more agents to acquire skills to work in non-agricultural sectors. The expansion of the sectors decreases the labor supply to agriculture as well as increases the supply of modern intermediate inputs to agriculture. Agricultural producers accordingly substitute the relatively cheap intermediate inputs for labor to produce a given level of an agricultural good, and, thereby, output per worker in agriculture is improved. Poor countries with less-developed credit markets are, therefore, far less productive in agriculture than rich countries with well-developed credit markets.

Keywords: productivity, credit market imperfection, agriculture, skill acquisition, human capital investment, occupational choice
JEL Classification codes: O11, O13, O16, O41

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1 Introduction

Cross-country labor productivity differences are enormous in agriculture but small in non-agriculture. Although labor productivity in agriculture is generally smaller than that in non-agriculture in almost all countries, the fact is particularly true in poor countries (Caselli 2005; Restuccia . 2008). As poor countries allocate their substantial labor force to agriculture, in which they are especially unproductive, the low labor productivity in the sector is responsible for their poverty and low aggregate productivity. Caselli (2005) argues that, if the agricultural labor productivity level in poor countries were the same as that in the U.S., world income inequality would virtually disappear. This result suggests the importance of agricultural productivity differences in understanding world income disparity. The aim of this paper is to present a simple theoretical model to demonstrate why labor productivity gaps between rich and poor countries are large to a great extent in agriculture.

One noticeable observation is that high agricultural labor productivity in rich countries is associated with the intensive use of intermediate inputs provided by non-agriculture. It is widely recognized that industrial development enables the supply of labor-saving intermediate inputs to agriculture at reasonable prices and that the intensive use of the intermediate inputs to produce a given quantity of agricultural output enhances agricultural labor productivity.[1] As Matsuyama (1992) also points out, the development of non-agriculture improves agricultural productivity through the supply of better and less expensive intermediate inputs, such as fertilizer, pesticide, drain pipes, and harvesting equipment, and analyzing models incorporating the feedback effects from non-agriculture to agriculture is essential for understanding the roles of agriculture in economic development.

Building on these insights, this paper proposes a simple theory to explain the massive variation in agricultural labor productivity differences across countries. The key elements of the model are non-homothetic preference and credit market imperfections. The first element, non-homothetic preference, is a tradition of development economics, and its implication is clear. Countries with low agricultural productivity have a large share of employment in the sector to meet food demand. The second element of credit market

[1] Notable literature includes Johnston and Mellor (1961), Gardner (1992), Johnson (1997), and Restuccia et al. (2008). For a case study in Japan, see Murata (2002).

imperfections plays central roles in this model. Agents have to invest in education and acquire special skills, or human capital, in order to work in a non-agricultural sector. Tight credit constraints make many agents impossible to cover costs of the human capital investment, and they have, thus, no choice but to work in agriculture, even though they are aware of higher returns from non-agricultural work.

In the model presented in this paper, credit market development enhances agricultural labor productivity through the expansion of non-agriculture. The development of credit markets enables more agents to invest in human capital and work in non-agriculture. The expansion of non-agriculture decreases labor supply to agriculture, increases supply of intermediate inputs to the sector, and thereby reduces the prices of the intermediate inputs relative to labor wages in agriculture. Because farmers substitute relatively cheap intermediate inputs for labor in order to produce a given level of an agricultural good, the agricultural labor productivity increases. Rich countries with well-developed credit markets, therefore, have high agricultural labor productivity, low labor share in agriculture, and low intermediate input prices. These results are consistent with the data by Caselli (2005) and Restuccia et al. (2008).

Economists have studied interactions between agriculture and non-agriculture to better understand the large productivity differences in agriculture and structural transformation of agricultural production. Murata (2002) develops a model with interdependence of agriculture and non-agriculture. The model can generate multiple equilibria, and the economy may be unluckily trapped into a bad equilibrium, which is characterized by labor-intensive agricultural production, a low degree of industrialization because of a small labor force reallocated from agriculture, and limited varieties of industrial inputs. Restuccia et al. (2008) calibrate a two-sector model and argue that direct and indirect barriers to modern intermediate input use can account for the large labor productivity gaps in agriculture across countries. An example of the direct barriers is the protection of domestic non-agricultural industries through tariffs and import quota, which directly raises prices of modern intermediate inputs. The indirect barriers are labor market distortions. Higher costs of migration that impede labor reallocation from agriculture to non-agriculture, together with institutionally protected urban wages, can make agricultural labor wages cheaper relative to the prices of the modern inputs. Such distortions in factor markets, according to Restuccia et al. (2008), play important roles in explaining the variation of sectoral and aggregate labor productivity differences across countries.[2]

This study explores a situation in which credit market imperfections are the source of labor immobility. Relative prices of modern intermediate inputs in agriculture are determined by the severity of the imperfections. Due to the imperfect credit markets, labor reallocation does not necessarily continue until payoffs from working in agriculture and non-agriculture are equalized; i.e., the non-arbitrage condition in labor markets does not hold under sufficiently imperfect credit markets, which is in contrast to the Restuccia et al. (2008) model. As already discussed, the current model predicts that, in poor countries, the prices of intermediate inputs for agriculture are high, the labor share in agriculture is high, and the labor wages in agriculture are low. The reason is the inability of the poor to finance human capital investment.

The effects of credit constraints on skill acquisition and occupational choice are widely studied both theoretically and empirically. For example, Galor and Zeira (1993) and Ljungqvist (1993) develop models in which credit constraints prevent human capital investment by the poor and cause unskilled poor agents to remain in the same status. On empirical research, cross-country and panel regressions by Flug et al. (1998) show that credit market development has significantly positive effects on school enrollment.[3] A theoretical study by Yuki (2008) has close structures to the present study. He investigates conditions for economies to accumulate human capital and accomplish the shift of employment and production from traditional agriculture to modern industry by considering an overlapping generations model in which individuals have non-homothetic preference and the absence of credit markets inhibits human capital investment to work in modern industry.

The plan of the rest of this paper is as follows. Section 2 describes the model and characterizes equilibrium. Section 3 discusses the results, and Section 4 states the conclusions.

[2]There are a number of other studies that attempt to account for the large productivity gaps in agriculture across countries. For example, Adomopoulos (2011) emphasizes the role played by differences in transportation systems across countries.

[3]Knight and Song (2003) also present data showing that credit market imperfections are a major obstacle for Chinese households to acquire skills to engage in non-agricultural activities.

2 The model

This section sets up a model and characterizes equilibria. The model is a one-shot static model with two sectors, each producing a different final good: an agricultural good and a manufacturing (non-agricultural) good. The markets for labor and the agricultural good are closed domestically, while the manufacturing good is internationally tradable at the exogenously given world price, which is normalized to one. Agents have non-homothetic preference with subsistence consumption needs in the agricultural good. Agricultural production uses unskilled labor and an intermediate input supplied by the manufacturing sector. Imperfect credit markets prevent human capital investment by the poor, and an extent of the imperfections determines labor share in the two sectors, the prices of the two goods, the agricultural wage, the intensity of intermediate input use in agriculture, and labor productivity in the sector.

2.1 Production technologies

There are two sectors in this economy, agriculture and manufacturing. The production function of agriculture is

$$Y_a = A_a X^\alpha L_a^{1-\alpha}, \tag{1}$$

where $\alpha \in [0, 1]$. Y_a is the agricultural output, X is the intermediate input provided by manufacturing, and L_a is unskilled labor.[4] As described in Introduction, this intermediate input, X, includes chemical fertilizer, pesticide, and others. A_a is the total factor productivity (TFP) in agriculture, which reflects any effect on agricultural productivity that does not come from labor and the intermediate input use, such as land, climate, and social infrastructures.

The production function of manufacturing is

$$Y_m = A_m L_m, \tag{2}$$

[4]Using Indian data, Jacoby and Skoufias (1997) find that returns to education in agricultural labor are negligible. Caselli and Coleman (2001) also find that educational attainment of workers in agriculture is consistently among the bottom 10 of 119 industries in the U.S. since 1940.

where Y_m is the manufacturing output used as a consumption good or the agricultural intermediate input, L_m is skilled labor, and A_m is its productivity. The input of capital services is omitted in both agriculture and non-agriculture. The specification and combination of these types of production functions is proposed by Restuccia et al. (2008). The markets are competitive, which leads to

$$p_a = \frac{1}{\alpha A_a} x^{1-\alpha}, \quad (3)$$

$$w_a = (1-\alpha) p_a A_a x^{\alpha}, \quad (4)$$

where $x \equiv X/L_a$. p_a and w_a are, respectively, the relative price of the agricultural good and the wage in agriculture. In manufacturing, $w_m = A_m$, where w_m is the wage in manufacturing.

2.2 Agents

There is a continuum of agents with unit mass. They live for two periods but consume only at the end of the second period. The utility function is, for some $\bar{a}$,

$$U(c_a, c_m) = \begin{cases} c_a & \text{if } c_a \leq \bar{a}, \\ \bar{a} + c_m & \text{if } c_a > \bar{a}, \end{cases} \quad (5)$$

where c_a and c_m are consumption of the agricultural and the manufacturing good, respectively. Agents care only about the agricultural good when they are poor, but, once they achieve $\bar{a}$ units of the agricultural good consumption, they devote all the remaining expenditures to the manufacturing good. This Stone-Geary utility function is used by Laitner (2000) to generate a demand pattern satisfying Engel's law.[5]

Let us consider the occupational choice of agents. They are heterogeneous only in terms of their initial endowments measured by the manufacturing good, which are uniformly distributed over the unit interval $[0, 1]$. In the first period, they choose to work either in agriculture as unskilled labor or in manufacturing as skilled labor through investment in education. The size of the investment is fixed as in Galor and Zeira (1993), Matsuyama (2004), and Yuki (2008), and I set the size at one. Agent i with his initial endowment e_i,

[5]This utility function provides closed-form expressions of equilibrium values.

therefore, has to borrow $1 - e_i$ in order to become a skilled worker. In the second period, agents supply labor, consume, and repay their loans. Agents can lend and borrow at a gross interest rate $r \geq 1$ determined at international financial markets. Since the wealth of agent i at the end of the second period is $w_a + re_i$ if he works in agriculture and $A_m - r(1 - e_i)$ if he works in manufacturing, $A_m - r(1 - e_i) \geq w_a + re_i$ must hold for him to work in manufacturing. That is,

$$A_m - r \geq w_a. \tag{PC}$$

This inequality (PC) is called the *profitability constraint* by Matsuyama (2004). When (PC) is binding, working in agriculture and manufacturing gives agents the same wealth at the end of their second period. No one, therefore, has a strong incentive favoring work in manufacturing over agriculture. On the other hand, all agents are eager to work in manufacturing when (PC) holds with strict inequality. Notice that, if (PC) is violated, all agents work in agriculture. However, as a result, the agricultural good is not produced, since no intermediate input is supplied for agriculture, which can never be realized in equilibrium.

Although agents can lend and borrow at the interest rate r, there exists a borrowing limit because borrowers can pledge themselves to repay only up to a fraction of their income. Specifically, in the spirit of Kiyotaki and Moore (1997), Aghion et al. (1999), and Matsuyama (2004), I assume that borrowers are not able to commit to repay more than λA_m, where $\lambda \in [0, 1]$. Agent i can borrow and invest in education if and only if

$$\lambda A_m \geq r(1 - e_i), \tag{BC}$$

where (BC) stands for the *borrowing constraint*. The left-hand side is the maximum he is able to commit to repay, and the right-hand side is the amount he has to repay.

2.3 Equilibrium

This subsection considers two cases based on whether (PC) is binding or not and discusses the conditions in which each case can be realized in equilibrium.

Before the two cases are presented, I will state a parameter restriction used throughout this paper:

$$\bar{a} < (1 - \alpha)A_a \left[\frac{\alpha}{1 - \alpha}(A_m - r) \right]^{\alpha}. \tag{6}$$

This inequality is likely to hold under small $\bar{a}$ and r or large A_a and A_m. The inequality ensures the existence of an equilibrium in which (PC) is binding and all agents consume $\bar{a}$ units of the agricultural good.

First, let us consider the case in which (PC) is binding. In this case, a sufficiently large number of agents work in manufacturing, so that w_a is raised high enough for (PC) to be binding. No one has a strong incentive to work in manufacturing since the payoffs from working in agriculture and in manufacturing are identical. Combining $w_a = A_m - r$, (3), and (4) yields

$$x = \frac{\alpha}{1-\alpha}(A_m - r), \tag{7}$$

$$p_a = \frac{1}{\alpha A_a}\left[\frac{\alpha}{1-\alpha}(A_m - r)\right]^{1-\alpha}. \tag{8}$$

Both the intensity of intermediate input use (x) and the price of the agricultural good (p_a) are increasing in A_m. Since an improvement of A_m raises the wage in manufacturing, agricultural workers must be compensated with a higher wage in order to make them indifferent between the two occupations, i.e., (PC) is binding. Farmers then substitute the intermediate input for labor, which results in the increase in x and p_a. Equation (8) also shows that a higher TFP in agriculture (A_a) is associated with a lower price of the agricultural good.

The wealth of agent i, W_i, does not depend on his occupation.

$$W_i = A_m - r(1 - e_i) \tag{9}$$

$$= w_a + re_i. \tag{10}$$

For simplicity, the following analysis focuses on the case in which all agents can consume $\bar{a}$ units of the agricultural good. In this case, $W_0/p_a = (A_m - r)/p_a > \bar{a}$, which is equivalent to (6) due to (8). Agents who are able to work in manufacturing do not need to do so since the results of working in agriculture and manufacturing are identical. Manufacturing workers, however, must satisfy (BC), since they have to invest in education in their first period. That is, they must satisfy

$$e_i \geq 1 - \frac{\lambda A_m}{r}. \tag{11}$$

By the market clearing condition for the agricultural good, $Y_a = A_a L_a x^\alpha = \bar{a}$, and (7), the labor share in agriculture is given by

$$L_a = \frac{\bar{a}}{A_a\left[\frac{\alpha}{1-\alpha}(A_m - r)\right]^\alpha}. \tag{12}$$

The labor share is decreasing in A_a, since less labor is required to produce $\bar{a}$ units of the agricultural good under a higher A_a. L_a is also decreasing in A_m, since a higher A_m leads to a higher agricultural wage because of the binding (PC). In order for these variables, x, p_a, and L_a, to constitute an equilibrium, the number of agents who are able to work in manufacturing must be greater than or equal to the number of agents who actually work in manufacturing. Specifically, the condition is $L_m = 1 - L_a \leq \lambda A_m / r$. By (12), the inequality is equivalent to

$$\lambda \geq \frac{r}{A_m}\left\{1 - \frac{\bar{a}}{A_a\left[\frac{\alpha}{1-\alpha}(A_m - r)\right]^{\alpha}}\right\}. \tag{13}$$

In summary, if (13) holds, then there exists an equilibrium in which (PC) is binding and all agents consume $\bar{a}$ units of the agricultural good.[6] In the equilibrium, a degree of the credit market imperfections, λ, does not have any effect on key variables, such as the labor share in agriculture (L_a), the intensity of intermediate input use in agriculture (x), and the relative price of the intermediate input ($1/p_a$). This is because credit markets are well-developed and a sufficiently large number of agents are able to invest in education and work in manufacturing. The agricultural wage is as high as the net return on the human capital investment, $A_m - r$, and no one is there who strictly prefers to borrow. Further improvement of credit markets has, hence, no effects on the key variables in the equilibrium.

Next, let us consider the case in which (PC) holds with strict inequality. All agents strictly prefer to work in manufacturing, but only agents who satisfy (BC), or (11), actually work in manufacturing, which leads to $L_m = \lambda A_m / r$. In order for (PC) to hold with strict inequality in equilibrium, λ must be small enough such that

$$\lambda < \frac{r}{A_m}\left\{1 - \frac{\bar{a}}{A_a\left[\frac{\alpha}{1-\alpha}(A_m - r)\right]^{\alpha}}\right\}. \tag{14}$$

The wealth of agent i at the end of the second period now depends on his occupation. Letting W_i^A and W_i^M denote the wealth of agent i obtained by working in agriculture and manufacturing, respectively,

$$W_i^A = w_a + re_i, \tag{15}$$

$$W_i^M = A_m - r(1 - e_i). \tag{16}$$

[6] $r = 1.05$, $\alpha = 0.4$, $A_a = 1$, $A_m = 2$, $\bar{a} = 0.1$, and $\lambda = 0.6$ satisfy both (6) and (13).

Since (PC) holds with strict inequality, $W_i^M > W_i^A$. Let us again find an equilibrium in which all agents can achieve an $\bar{a}$ level of the agricultural consumption: $W_0^A/p_a = w_a/p_a > \bar{a}$. Since $Y_a = \bar{a}$ and $L_a = 1 - L_m = 1 - (\lambda A_m)/r$ in equilibrium,

$$x = \left[\frac{\bar{a}}{A_a \left(1 - \frac{\lambda A_m}{r}\right)} \right]^{\frac{1}{\alpha}}, \tag{17}$$

and combining (3) and (17) gives

$$p_a = \frac{1}{\alpha A_a} \left[\frac{\bar{a}}{A_a \left(1 - \frac{\lambda A_m}{r}\right)} \right]^{\frac{1-\alpha}{\alpha}}. \tag{18}$$

An increase in A_m raises the intensity of intermediate input use in agriculture (x) and the relative price of the agricultural good (p_a). The increase in A_m relaxes the borrowing constraint through raising the pledgeable income λA_m and thereby increases the number of agents working in manufacturing. The consequent reduction in the number of agricultural workers must be compensated with the use of the intermediate input (X) when producing $\bar{a}$ units of the agricultural good. The improvement of A_m, therefore, raises x, and p_a is raised as a result. An increase of A_a, on the other hand, decreases the intensity of the intermediate input use in agriculture. The degree of credit market imperfections determines the number of credit-constrained individuals, which is identical to the number of agricultural workers. Under the given size of labor, the improvement of A_a reduces the required amount of the intermediate input (X) in order to produce $\bar{a}$ units of the agricultural good, which means the reduction of x. The price of the agricultural good is low under a high agricultural TFP. The condition for $w_a/p_a > \bar{a}$ is equivalent to $\lambda > \alpha r/A_m$ by (3), (4), and (17).

In summary, if

$$\alpha \frac{r}{A_m} < \lambda < \frac{r}{A_m} \left\{ 1 - \frac{\bar{a}}{A_a \left[\frac{\alpha}{1-\alpha}(A_m - r)\right]^{\alpha}} \right\}, \tag{19}$$

then there exists an equilibrium in which (PC) holds with strict inequality and all agents consume $\bar{a}$ units of the agricultural good. In the equilibrium, the improvement of credit markets enhances the use of the intermediate input in agriculture through the reduction of the relative price of the input ($1/p_a$). This is because the improvement enables more agents to invest in education and work in manufacturing.

3 Results

This section contains a discussion of the main interest. As described in the Introduction, labor productivity gaps between developed and developing countries are extremely large in agriculture. Moreover, credit market imperfections are severe in developing countries according to a literature survey by Banerjee (2003). The model provides an explanation for the large labor productivity differences in agriculture in terms of imperfections in credit markets. In addition, as shown in Section 2, the model accounts for other characteristics of agriculture in poor countries, such as labor-intensive production and high intermediate input prices.

The agricultural labor productivity $Y_a/L_a = A_a x^\alpha$ in equilibrium is

$$\frac{Y_a}{L_a} = A_a \left[\frac{\alpha}{1-\alpha}(A_m - r) \right]^\alpha \tag{20}$$

when (PC) is binding and

$$\frac{Y_a}{L_a} = \frac{\bar{a}}{1 - \frac{\lambda A_m}{r}} \tag{21}$$

when (PC) holds with strict inequality. The agricultural labor productivity increases in λ when λ is small. Once λ reaches the range of (13), however, the productivity is independent of λ because λ has no effects on labor share in either sector. When credit constraints are so tight that (PC) holds with strict inequality, the improvement of credit markets enables more agents to invest in education and increases the number of manufacturing workers. The expansion of manufacturing lowers the relative price of the intermediate input, which gives farmers incentive to substitute the relatively cheap intermediate input for labor in the production of $\bar{a}$ units of the agricultural good. This is the mechanism how the improvement of credit markets enhances agricultural labor productivity. Poor countries with less-developed credit markets are, therefore, far less productive in agriculture than rich countries with mature credit markets. In concrete terms, the United States has highly developed credit markets, and its agricultural labor productivity is one of the highest in Caselli's (2005) data. In contrast, access to financial services is quite limited in Nepal, and its agricultural labor productivity is at a very low level in the same data set.[7]

[7]Ferrari et al. (2007) provide a detailed description on the access to financial services in Nepal. For example, only 26 percent of Nepalese households have a bank account.

Which of the two factors in agricultural production is relatively cheaper, the modern intermediate input or the agricultural labor, is a major determinant of labor productivity in agriculture. Restuccia et al. (2008) argue that exogenous variations in barriers to the use of a modern intermediate input determine the price of the input relative to the agricultural labor wage and, therefore, account for the large cross-country productivity gaps in agriculture. In the present study, the degree of imperfections in credit markets determines the relative price of the intermediate input and the labor wage in agriculture. Needless to say, introducing the barriers in the current model would add another source of agricultural productivity differences. Specifically, the cost of education is one in the model, but allowing the variations in the cost would lead to differences in agricultural labor productivities even under perfect credit markets. In other words, a larger cost of education, which corresponds to an indirect barrier in Restuccia et al. (2008), would be associated with lower agricultural labor productivity.

The total factor productivity in each sector can also influence agricultural labor productivity. An improvement of A_m has positive effects on agricultural labor productivity regardless of whether (PC) is binding or not. The increase in A_m raises agricultural labor productivity by relaxing the borrowing constraint when it is tight enough and the labor productivity is given by (21); the rise in A_m increases the pledgeable income and enables more agents to work in manufacturing, which makes the modern intermediate input available to farmers at a cheaper price and thereby increases the labor productivity in agriculture. A rise in A_m also enhances agricultural labor productivity when credit markets are well-developed and the productivity is given by (20). This is because a higher A_m means higher wage in agriculture when (PC) is binding and farmers substitute the intermediate input for relatively expensive labor.

An improvement of A_a, on the other hand, has no effects on labor productivity when the borrowing constraint is tight and (PC) holds with strict inequality. The reason is that the number of agricultural workers, or credit-constrained individuals, is solely determined by the degree of credit market imperfections, and the amount that the agricultural sector must produce is the constant $\bar{a}$. The results of the comparative statics have an interesting policy implication. It is often argued that agricultural productivity growth is a precondition for economies to reallocate labor from agriculture to manufacturing and initiate a takeoff into modern economic growth. In consideration of whether government policies should place emphasis on improving the TFP of agriculture or manufacturing, however, how the policies affect the borrowing constraints of agents should be carefully examined.

4 Conclusion

Presented in this paper are the implications of credit market imperfections for the large agricultural labor productivity differences across countries based on the well-established theory and evidence that credit market imperfections are an obstacle for human capital investments. In the model presented here, agents need to get an education and acquire skills to work in manufacturing (non-agricultural) sectors. The development of credit markets increases the number of manufacturing workers, which reduces the relative prices of modern intermediate inputs in agriculture that are supplied by manufacturing. This makes it possible for farmers to use the intermediate inputs intensively, and output per worker in agriculture thereby increases. The model predicts that, in poor countries with underdeveloped credit markets, agriculture is labor-intensive, and its labor productivity is remarkably low in comparison to that of rich countries with mature credit markets.

The model has some policy implications besides the obvious one that directly improving credit markets enhances agricultural labor productivity. In particular, the marginal increase in manufacturing TFP always improves agricultural labor productivity, while the increase in agricultural TFP does not have much contribution to the improvement of agricultural labor productivity. The reason is that the improvement of TFP in manufacturing raises the return of education and improves the ability of agents to repay their loans, but the improvement of TFP in agriculture does not have such an effect. Based on the observation that food is a basic necessity, it is often argued that productivity growth in agriculture is a precondition of industrialization and a takeoff into modern economic growth. However, this result suggests that, in the discussion of government policies that improve a sectoral TFP, their effects that operate through credit constraints should be given careful consideration.

It would be interesting to extend the model to a dynamic setting by specifying the source of the heterogeneity of agents. There could be additional insights on timing of agricultural modernization or appropriate government policies from such a dynamic model. This subject remains for further research.

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