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Can unobserved heterogeneity in farmer ability explain the inverse relationship between farm size and productivity

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Abstract

The well-known inverse relationship between farm size and productivity is usually explained in terms of diminishing returns with respect to land and other inputs coupled with various types of market frictions that prevent the efficient allocation of land across farms. We show that even in the absence of diminishing returns one can provide an alternative explanation for this phenomenon using endogenous occupational choice and heterogeneity with respect to farming skills.

Keywords: Farm size and productivity; Land reform; Rural land markets

JEL classification: O13; Q15

1. Introduction

Evidence suggests that there is an inverse relationship between farm size and productivity in agriculture.[1] The usual explanation for this is based on diminishing returns, and the presence of frictions in the land, credit, labor or insurance markets that prevent the efficient allocation of land. For example, Eswaran and Kotwal (1986) examine economies in which labor is subject to supervision

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[1]Berry and Cline (1979) compute the ratio of productivity of small farms to the largest farms. The index is 5.63 in Northeast Brazil, 2.74 in Punjab, Pakistan, and 1.48 in Muda, Malaysia. Using the ICRISAT Indian village surveys, Rosenzweig and Binswanger (1993) show that the profit rates for poorer farmers are systematically higher. Binswanger et al. (1995) and Ray (1998) (Chapter 12) provide very good surveys of the literature.

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problems and land provides better access to credit.[2] They show that because of increasing marginal cost of supervision, the land to labor ratio is higher for richer farmers, which leads to decreasing output per hectare with respect to farm size. Small farmers have advantages in labor supervision because they rely mostly on family labor. This line of argument suggests that any type of land reform that reduces the inequality of landholdings will have a positive effect on productivity.

In this note we examine the role of the assumption of diminishing returns (or, equivalently, increasing marginal cost of some input) to explain this phenomenon. Suppose there are constant returns to scale and because of some frictions in the land or the credit market, how much land a farmer operates depends on his wealth. Can we still observe an inverse relationship between farm size and productivity? We show that with endogenous occupational choice and heterogeneity with respect to farming skills, the answer is, surprisingly, yes and follows from a simple self-selection argument. The result is, of course, strengthened if there are diminishing returns. We make the assumption of constant returns not necessarily because we think it is more plausible, but simply to highlight an effect that has been ignored in the literature, namely, the potential importance of unobserved heterogeneity in farmer quality and self-selection through occupational choice.[3]

In the next section we provide the formal model, and make some concluding remarks in Section 3.

2. The model

The key assumption in our model is that the credit market does not exist. Our results go through if the credit market is not necessarily non-existent but imperfect, in the sense that how much land you can lease in or buy depends on how wealthy you are. It is well-known that due to the presence of transactions costs of various kinds, coupled with the weakness of the legal system of loan enforcement, credit markets do not work properly in underdeveloped countries (Ray, 1998). If in addition we assume there are diminishing returns with respect to land, or with respect to the labor supervision technology, the inverse relationship between farm size and productivity would follow directly. We want to show that even if the technology does not display diminishing returns, with endogenous occupational choice and heterogeneity with respect to farming skills, we could observe an inverse farm size–productivity relationship.

We assume that the population has a mass normalized to 1 and an exogenously given distribution of wealth $G(a)$. All individuals also have an endowment of 1 unit of labor which is supplied inelastically, either in their own farm or working in someone else's farm as an agricultural laborer. A single agricultural good, assumed to be the numeráire, is produced and consumed. Although the population is completely homogeneous with respect to the ability to work, there is heterogeneity in farming skills. Therefore, a farm belonging to a skilled peasant is more productive than a farm managed by an unskilled peasant. The distribution of skills is assumed to be independent of the distribution of wealth. For any given level of wealth, a fraction α of individuals are skilled and the remaining fraction of $1-\alpha$ individuals are unskilled.

An individual can split his labor endowment between different occupations: let λ denote the fraction of time an individual works as a laborer in someone else's farm, while with the remaining

[2] See Feder (1985) for a related model.

[3] For example, Rosenzweig and Binswanger (1993) control for land quality but not farmer ability.

$1-\lambda$ units of his time he supervises production in his own farm. Whether a person is skilled or unskilled has no effect on his productivity as a worker and so the wage rate is uniform and, to simplify, it is paid after production.

We assume that farmers can produce output using a fixed-coefficients production function which requires one worker for every unit of land. There are no supervision problems, so one farmer can in principle have a very large farm without any loss of efficiency. Let the (constant) marginal product of land be denoted by q_s in a skilled farmer's farm, and q_u in an unskilled farmer's farm with $q_s > q_u > 0$. The end of period income is entirely used for consumption. The consumption of an i-type individual ($i=$ s,u) who spends λ units of his time working as a laborer and $1-\lambda$ units of his time supervising his own farm is:

$$\begin{aligned} c_i &= a - pT + \lambda w + (1-\lambda)(q_i - w)T \\ &= \lambda(a - pT + w) + (1-\lambda)[a + (q_i - w - p)T], \end{aligned}$$

where w is the wage rate, p is the rental rate of land, and T is the farm size. As mentioned earlier, there is no credit market. Agents have no endowments of land and cannot borrow to finance land purchases. There is a competitive land rental market.[4] For the moment we take the wage rate w and the rental rate p as given exogenously. The access to land is restricted by initial wealth. Formally, the lack of a credit market implies that $pT \le a$ for a peasant with initial wealth a. Also, any money left after paying rent for the land can be consumed after the end of the period without any discounting or depreciation.

Given the linearity of the technology, an i-type individual will either be a full time worker, or a full time farmer. This also implies that full time farmers will demand $T = a/p$, which is the maximum farm size affordable, and full time workers will choose $T = 0$. Substituting the land demand, the final wealth of an i-type individual becomes

$$c_i = \lambda(a + w) + (1-\lambda)\left(\frac{q_i - w}{p}\right)a,$$

where $\lambda = 0$ for full time farmers and $\lambda = 1$ for full time workers. The level of wealth at which an i-type individual will be indifferent between the two occupations is defined as:

$$a_i \equiv \frac{wp}{q_i - w - p}.$$

Note that $q_u < q_s$ implies that, for all positive w, $a_s < a_u$. Now we are ready to prove our main result:

Proposition 1. *The average farm size of skilled farmers is smaller than that of unskilled farmers.*

Proof. Note that

$$h(x) = \frac{1}{[1 - G(x)]}\int_x^\infty \frac{a}{p}\,\mathrm{d}G(a)$$

[4] In a static model there is no difference between land sales and a land rental market, but we favor the latter interpretation as land sales markets are relatively thin in most developing countries.

is the average farm size of a class of farmers with wealth equal or greater than x. Notice that by the definition of $h(x)$, $h(x) > x/p$. Then, differentiating with respect to x and using Leibniz's rule, we get

$$\begin{aligned} h'(x) &= \frac{1}{p}\left[-\frac{xg(x)}{1-G(x)} + \frac{g(x)}{[1-G(x)]^2} \int_x^{\infty} ag(a)\,\mathrm{d}a \right] \\ &= \frac{1}{p}\,\frac{g(x)}{1-G(x)}[ph(x) - x] > 0. \end{aligned}$$

Therefore, $a_u > a_s$ implies that a low-type farm is, on average, larger than a high-type farm. Given the production functions it readily follows that output per unit of land is higher on average in smaller farms compared to larger farms. □

The following corollary is immediate:

Corollary to Proposition 1. *If we compare the average productivity of all farms and do not control for the heterogeneity of farmer skills, we will find that smaller farms are more productive. Controlling for farmer heterogeneity one will find no relationship between farm size and productivity.*

Even without diminishing marginal returns, the model is therefore compatible with the inverse relationship between farm size and productivity. The intuition is as follows. The payoffs under all three occupations (worker, unskilled farmer, skilled farmer) are increasing in a. For a given increase in a, the highest marginal return is for skilled farmers, the second highest for unskilled farmers and the third highest for workers.[5] This means the payoffs for skilled farmers exceed those of workers starting from a lower wealth level than that of unskilled farmers. That is, the marginal skilled farmer is poorer than the marginal unskilled farmer. Given independence of wealth and talent, the distribution of land is the same for both skilled and unskilled individuals. As a result, the average skilled farmer is poorer than the average unskilled farmer. Given the linearity of technology, this means the farm size of skilled farmers is lower than that of unskilled farmers.

A brief discussion about how w and p are determined in market equilibrium is in order. We assume that the economy has a fixed supply of $\bar{T}$ hectares of land available for rental. Given the fixed-coefficients technology which uses 1 unit of labor per unit of land, the demand for land and labor are the same, namely,

$$\frac{1}{p}\left[\alpha \int_{a_s}^{a_u} a\,\mathrm{d}G(a) + \int_{a_u}^{\infty} a\,\mathrm{d}G(a) \right],$$

[5]For full time farmers, we have

$$\frac{q_i - w}{p}a > a + w > a,$$

which implies that

$$\frac{q_s - w}{p} > \frac{q_u - w}{p} > 1.$$

which is decreasing in p and w (recall that a_u and a_s are increasing in p and w). The supply of labor is $G(a_s)+(1-\alpha)[G(a_u)-G(a_s)]$, which is increasing in w and p. We assume there is a subsistence technology, which requires 1 unit of labor and no capital or land to operate and yields a return of $\underline{w}$. This wage rate, which defines the lower bound to the market wage rate, is assumed to be strictly less than q_s, otherwise no one will ever want to become farmers. Several cases are possible depending on the endowment of land $\bar{T}$ (recall that population size is normalized to 1) and the wealth distribution. The one we focus on in this note is where the wealth distribution is such that there is an excess supply of labor even when $w=\underline{w}$ which implies the market wage is $w^*=\underline{w}$. Assuming that land is scarce (i.e. $\bar{T}$ is not too high), there will be some equilibrium rental rate $p^*>0$ which will clear the land market. We focus on the case where $p^*<q_u-\underline{w}$, because otherwise we would not observe unskilled individuals becoming farmers. The environment we assume corresponds to a land-scarce economy with surplus labor (i.e. a high fraction of wealth-constrained individuals who have no choice but to work for subsistence wages), in other words, a typical developing country.

An interesting policy implication of this model is that any type of land reform that takes land from the rich and gives it to the poor is not going to improve productivity. Suppose the policymaker cannot observe the skill level of a farmer. Then the expected income of an individual as a function of initial wealth will appear as presented in Fig. 1 to the policy maker. For $a \le a_s$, wealth does not contribute to an individual's income. For $a \in [a_s,a_u]$ an individual who operates a farm must be skilled and so the slope of the curve in this region is $(q_s-w-p)/p$. For $a \ge a_u$, a farmer could be either skilled or unskilled. Given that wealth and skill are assumed to be uncorrelated, the average increase in income of an individual as his initial wealth increases is $[\alpha q_s+(1-\alpha)q_u-w-p]/p$. It readily follows that any redistribution within the wealth intervals $[0,a_s],[a_s,a_u]$ and $[a_u,\infty)$ will have no effect on productivity, contrary to the prediction of the argument based on diminishing returns. More interestingly, any redistribution from the very poor (i.e. $a \in [0,a_s]$) to middle farmers (i.e. $a \in [a_s,a_u]$) will increase inequality but also improve average productivity. This is in sharp contrast with the argument based on diminishing returns. Redistribution from rich farmers (i.e. $a \in [a_u,\infty)$) to middle farmers will reduce inequality and improve average productivity at the same time, as under the usual argument based on diminishing returns.

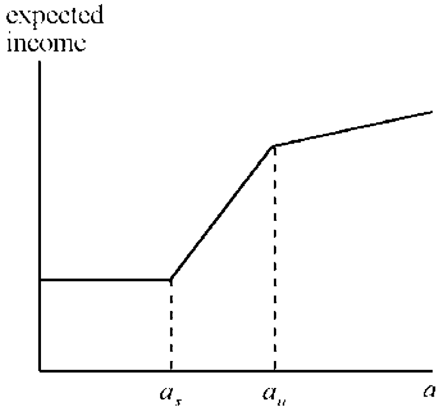

Fig. 1. Expected income, $E(c_i-a)$, as a function of a.

3. Conclusion

Our analysis shows that the well-known inverse relationship between farm size and productivity can be a result of imperfect credit markets and heterogeneity in farmer skills even if there are no diminishing returns with respect to any input. The result is based on the fact that, at a given level of wealth, skilled peasants are more likely to become farmers than unskilled peasants. In other words, the opportunity cost of a skilled peasant to become a wage worker is higher. As a consequence, unless econometric analysis of the relationship between farm size and productivity carefully controls for the ability of the farmer, there will be a selection bias that will overstate the true extent of the inverse relationship between farm size and productivity.

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