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Land tenure, population, and long-run growth

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Abstract This paper brings together the development literature on land tenure with current research on population and long-run growth. Landowners make a decision between fixed rent, fixed wage, and sharecropping contracts to hire tenants to operate their land. The choice of tenure contract affects the share of output going to tenants, and within a simple unified growth model, this affects the relative price of food and therefore fertility. Fixed wage contracts elicit the lowest fertility rate and fixed rent contracts the highest, with sharecropping as an intermediate case. The implications of this for long-run growth depend on the assumptions one makes about scale effects in the aggregate economy. With increasing returns to scale, as in several models of innovation, fixed rent contracts imply higher growth through a market size effect. Without such increasing returns, though, fixed rent contracts reduce output per capita through a depressing effect on accumulation.

Keywords Agriculture · Land tenure · Endogenous fertility

JEL Classification N10 · O41 · Q10

1 Introduction

From small family farms to large-scale plantations employing large numbers of workers, there are a multitude of ways of organizing agricultural production.

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The details of these arrangements have been a subject of interest to economists for a very long time, with Alfred Marshall (1920) making one of the first systematic explorations of the efficiency of sharecropping.

The field of development economics has, since then, examined the nature of land tenure in intense detail. Cheung (1969) suggested that Marshall's analysis was incomplete and proposed that tenure contracts would specify labor inputs or an equilibrium could not be sustained. However, Cheung's analysis makes share tenancy and fixed rent contracts identical, which does not match empirical evidence. Stiglitz (1974) and Newberry (1977) incorporated uncertainty and risk in order to explain how share tenancy could persist even though it appeared inefficient while Eswaran and Kotwal (1985) considered differences in ability between landowners and tenants as the driver of tenure relationship.[1] Although we have rich theoretical models and a host of empirical studies regarding tenure, this literature has not considered the long-run implications of land tenure relationships.

Existing research that does examine the relationship of population and growth, on the other hand, has generally ignored land tenure completely. This is true despite the fact that most rely on land as a fixed factor of production to generate a Malthusian relationship between fertility and income (Galor and Weil 1999, 2000; Galor and Moav 2002; Galor 2005; Hansen and Prescott 2002; Kremer 1993; Jones 2001; Doepke 2004; Kogel and Prskawetz 2001; Strulik and Weisdorf 2008). Similarly, work that looks at structural transformation and the allocation of labor between sectors has also typically assumed away questions of land tenure even if a land market is allowed to exist (Gollin et al. 2007; Vollrath 2009; Galor et al. 2009; Restuccia et al. 2008).

The purpose of this paper is to bring these two literatures together and analyze whether differences in land tenure relationships may influence long-run population and growth processes. To do this, I employ the general structure of Eswaran and Kotwal (1985) to describe the conditions under which landowners will choose fixed rent, fixed wage, or sharecropping contracts for their tenants. The key parameters in this structure are the relative abilities of landowners and tenants in managing farms and supervising labor, and then landowners select the tenure system that nets them the greatest return. At a specific combination of parameters, landowners will be indifferent between the type of tenure used to engage tenants, a situation I focus on in the analysis because it allows us to look purely at the effects of tenure system as opposed to productivity differences in supervision and management.

This tenure decision is then placed within a simple growth model similar in design to the work of Strulik and Weisdorf (2008). Individuals optimize over consumption and fertility, where fertility depends on the relative price of agricultural goods. The model has both an agricultural and non-agricultural sector, and labor is mobile between them. The system of land tenure determines the

[1]This review is incredibly incomplete. The reader is referred to Otsuka et al. (1992) for a broader description of the literature.

return to working in that sector. Under fixed rent systems, tenants earn the returns to supervision and management, making it more lucrative to work in agriculture. The relative price of food is driven down, and this raises fertility.[2] Under fixed wage systems, however, the landowners capture the returns to supervision and management and tenants are only hired for physical labor. Fewer individuals will choose to work in agriculture, raising food prices, and therefore fertility falls.[3] The essential element driving these differences is the share of output that goes to tenants versus owners. As the tenant's share rises, so does fertility.

Ultimately, fixed rent systems result in higher fertility and a larger population density in the Malthusian steady state. Fixed wage systems lead to lower fertility and lower densities. The implication is that the method of organizing agricultural production can have significant effects on long-run population size.[4]

Does this matter for growth and income per capita? That depends on the sources of growth. If accumulation of capital is the primary source, then higher fertility rates under the fixed rent contract will lower steady-state income per capita. However, recent research has indicated that capital accumulation is not the major reason for differences in output per capita (Hall and Jones 1999; Klenow and Rodriguez-Clare 1997; Caselli 2005). In contrast to accumulation, models of innovation often depend positively on the size of population as this creates larger profits (Jones 2003 and 2005). For a generic model of innovation, the rate of population growth will be a determinant of the steady state growth rate in output per capita. Thus, a land tenure system that provides higher fertility (as the fixed rent contract does) will actually lead to higher *growth*. So the overall effect of land tenure systems on income per capita depends on the importance of accumulation and innovation, and it is possible that fixed wage systems may have higher initial levels of income (due to accumulation) but slower growth (due to innovation).

One interesting possibility linking land tenure and long-run development has to do with family farming. In a recent paper, Easterly (2007) explores the relationship between inequality and output per capita. In the empirical work, he shows that the percentage of farms that are family operated historically is a significant predictor of current inequality levels, and using this as an instrument shows higher inequality causes lower output per capita. This may, from the perspective of this paper, be explained more directly as a consequence

[2] The focus on the relative cost of children in determining outcomes is shared with work by Galor and Mountford (2008) and Moav (2005).

[3] Sharecropping is shown to be an intermediate case between these two extremes.

[4] While showing the potential impact of land tenure on long-run development, the issue of property rights is not addressed. Landowners do not exert any market power that allows them to capture more than the marginal return to land. Binswanger et al. (1995) discuss historical situations in which greater rents were available though control of labor and credit markets, a situation formalized by Conning (2002) in his examination of land markets when owners act as oligopolists. Similarly, the potential for population density to influence the technology available and hence the tenure system employed, as in Boserup (1965), is not addressed.

of the tenure system involved. Family farms can be described as fixed wage operations in which the owner (the farmer) hires in his own labor (and possibly additional labor if necessary). Fixed wage systems lead to lower fertility and hence would be associated with higher income per capita if accumulation of capital was relevant for income levels. Easterly's results, then, may not reflect the effect of inequality per se but rather the reduced form effect of a land tenure system that encourages lower fertility and hence higher capital per person. This explanation would complement existing work on the benefits of low land inequality working through the political process, as in Binswanger and Deininger (1997), Engerman and Sokoloff (1997), and Galor et al. (2009).

To proceed, first the structure of land tenure systems is described as well as the conditions upon which different systems are chosen. Then the long-run model of population is described and the implications of the tenure relationships are shown. Finally, the implications for these results in the context of growth models of accumulation or innovation are explored.

2 Agricultural production and tenure relationships

To describe production and tenure, I follow the framework of Eswaran and Kotwal (1985). They provide a way of understanding why particular forms of land tenure may arise, given a set of conditions related to how labor and landowners vary in their capabilities. Their work and mine by extension do not attempt to explain *why* there are labor market imperfections, issues with monitoring, and/or management ability. Rather, this framework will be useful in describing how differences in these elements of the rural production sector will influence long-run outcomes through the share of output that is earned by laborers.

Agricultural production on any farm is given by

$$Y_A = AM^{\delta} E^{\beta} X^{1-\delta-\beta} \tag{1}$$

where A is total factor productivity, M is management (a separate labor input from physical work), and X is land. The factor of production E is the effective physical labor input, and this is described more specifically as

$$E = S^{\epsilon} P^{1-\epsilon} \tag{2}$$

which says that effective labor is a Cobb–Douglas combination of supervision, S, and physical labor, P. The value of ϵ indexes the importance of the supervision to productive work. If $\epsilon = 0$, then there is no monitoring problem and physical labor enters the production function with an elasticity of β. As ϵ goes to one, supervision becomes more important due to some imperfections in the labor market.

There are a total of L individuals in the economy. Of these, N are landowners, and for simplicity, it is assumed that each of the N owners holds exactly the same amount of land. Thus, each holds X/N in land. These landowners will be ultimately responsible for deciding which type of tenure relationship to offer to tenants and will do so to maximize their income. All individuals, owners and non-owners alike, provide one unit of labor inelastically to the market. They face an outside option of working in the non-agricultural sector for a wage of W.

The crucial distinction between tenure systems will be how the management (M) and supervision (S) inputs are provided. Under a fixed wage system, the landowners themselves provide these two inputs, while a fixed rent system has the tenant providing both management and supervision. Sharecropping will split the responsibilities so that owners provide management while tenants do the supervision.

As in Eswaran and Kotwal's work, one of the drivers of tenure systems is differences in ability between landowners and non-owners in their management and supervision ability. Mathematically, a unit of landowners' time is equivalent to only $0 < \gamma_N < 1$ units of supervision. Their management ability is not distorted. On the other side, non-owners have no distortion in their supervision ability, but a unit of their time is worth only $0 < \gamma_T < 1$ units of management. The values of γ_N and γ_T index exogenously given distortions in abilities. If one thinks of the M input as a proxy for capital services, then landowners would have an advantage in providing this because they can offer their land as collateral. On the other side, if non-owners tend to provide labor as family units, the issues of monitoring may be less severe. Again, the purpose here is not to provide an explanation for why these distortions exist but rather to explore the ramifications of these distortions for long-run growth and population size.

Given this setup, the various types of tenure systems and their implied return to landowners are described in turn.

Fixed wage contracts. In this tenure relationship, the landowner does all supervision and all management, hiring in workers to provide physical labor, P, only.[5] Given the Cobb–Douglas output function and a competitive market for physical labor, agricultural laborers earn the fraction $(1-\epsilon)\beta$ of output.

Note that because landowners provide the supervision (S) in this system, there is a loss in productivity. Output is scaled down by the factor $\gamma_N^{\epsilon\beta}$. To define the return to landowners, an intermediate step will be very useful here and in the following sections. Define

$$\hat{Y}_A = \left(\frac{A\delta^{\delta}(\epsilon\beta)^{\epsilon\beta}(\beta-\epsilon\beta)^{(1-\epsilon)\beta}}{W^{\delta+\beta}} \right)^{1/(1-\delta-\beta)} X \qquad (3)$$

[5]Note that there is nothing restricting landowners from being hired-in as the physical labor in this tenure system or any other. The differences arise only from whether management and supervision effort are open activities to non-owners. In the fixed wage contract, non-owners do not provide these services.

as agricultural output in a fully competitive market for all three labor inputs where they each are provided at the wage rate of W.[6] Given this, output in the fixed wage system can be written as

$$Y_A^{\mathrm{FW}} = \gamma_N^{\epsilon\beta} \hat{Y}_A \tag{4}$$

and the return to landowners (as a group) is

$$R^{\mathrm{FW}} = (1 - \beta + \epsilon\beta)\gamma_N^{\epsilon\beta} \hat{Y}_A. \tag{5}$$

Fixed rent contracts. Under this tenure relationship, the landowner charges a fixed rent to tenants for use of the land. The tenants provide both the supervision and management of production. The landowners, taking into account that tenants will act to maximize output but that they have an outside option of working in the non-agricultural sector, will set the fixed rent such that the tenant earns exactly the outside option.

Tenants earn $(1 - \epsilon)\beta$ of output for physical work (P), $\epsilon\beta$ of output for supervision (S), and δ of output for management (M). Because laborers are inefficient managers, total output is $Y_A^{\mathrm{FR}} = \gamma_T^{\delta} \hat{Y}_A$. This implies that the return earned by landowners in this contract is

$$R^{\mathrm{FR}} = (1 - \beta - \delta)\gamma_T^{\delta} \hat{Y}_A. \tag{6}$$

One thing to note is that the *share* of output paid to the landowner $(1 - \beta - \delta)$ is smaller than the share paid in a fixed wage situation. However, the total return may be higher under fixed rent if γ_N is particularly small and/or γ_T is relatively large.

Sharecropping. This setup provides a means for the landowner to maximize output by engaging themselves as manager and hiring agricultural laborers to be supervisors, avoiding any distortions to productivity. The issue with this tenure relationship is in providing incentives to both parties to provide the output-maximizing input of management and supervision. There are various ways to think about how this negotiation operates, but Eswaran and Kotwal make the case that thinking about the non-cooperative simultaneous choice game between owner and laborer is appropriate.

The solution to the sharecropping problem can be described as follows. Let the profit from the farm be written as

$$\Pi(M, S) = \max_P Y_A - WP \tag{7}$$

which is the maximized value of output minus physical labor costs, given the values of management and supervision. Let P^* be the optimal amount of labor chosen.

[6]Throughout this section, it is assumed that the number of landowners satisfies $N/L \geq \theta(\beta\epsilon + \delta)/w$, which assures that the solutions for M and S are all interior and satisfy the condition that $M + S \leq 1$. This ensures that it is feasible for a single owner (or tenant) to provide the optimal management and supervision input.

The prospective sharecropper, who will act as the supervisor, earns the share ϕ of the profits after physical labor is paid for. He thus solves

$$\max_{S} \phi \Pi(M, S) - WS \tag{8}$$

giving $\hat{S}(M, \phi)$ as the optimal supervision input given the outside option of a wage W for supervision time. Similarly, the landowner who acts as the manager solves

$$\max_{M} (1 - \phi)\Pi(M, S) - WM \tag{9}$$

for $\hat{M}(S, \phi)$ where the owners have a similar outside option for time. Because the tenant/supervisor is only earning ϕ of profits, we have the classic incentive problem of Marshall (1920) at work here. However, note that the owner/manager has a similar incentive problem. While these incentive problems will induce both parties to exert less effort than optimal, the trade-off is that there is no productivity distortion from either γ_N or γ_T. Thus, sharecropping may end being the optimal choice for the landlord.

A Nash equilibrium solves $\hat{S}(M, \phi)$ and $\hat{M}(S, \phi)$ simultaneously, yielding values $S^*(\phi)$ and $M^*(\phi)$, which are the optimal responses given the sharing rule ϕ. Now, to complete the solution, we allow the landowner to set the value of ϕ in the sharecropping contract, taking into account the optimal responses and knowing that the sharecropper has an outside option of W. The landlord thus solves

$$\max_{\phi} \Pi(M^*(\phi), S^*(\phi)) - WM^*(\phi) - WS^*(\phi) \tag{10}$$

which incorporates the fact that the landowner can drive the return of the sharecropper down to his outside option. The optimal sharing rule is ϕ^*.

This process results in the following distribution of agricultural output. Agricultural laborers, in total, earn $(1 - \epsilon)\beta$ of output for providing physical work. They also, as sharecroppers, earn $\phi^*\epsilon\beta + \phi^*\delta$ as their share of the returns to supervision and management.

There is a distortion to output, given that both managers and sharecroppers are not receiving their full marginal product. Output under sharecropping is $Y_A^{\text{SH}} = \phi^{*\epsilon\beta}(1 - \phi)^{*\delta}\hat{Y}_A$, and so the return to landowners is

$$R^{\text{SH}} = [1 - \beta + (1 - \phi^*)\epsilon\beta - \phi^*\delta]\phi^{*\epsilon\beta}(1 - \phi)^{*\delta}\hat{Y}_A. \tag{11}$$

In terms of just the share of output earned, note that sharecropping nests the fixed wage and fixed rent systems. As ϕ^* goes to one, the share of output goes to $(1 - \beta - \delta)$, similar to a fixed rent outcome. As ϕ^* goes to zero, the share going to landowners is $(1 - \beta + \epsilon\beta)$, which is the same as a fixed wage system. Under very general conditions, though, the value of ϕ^* will be close to one half, as established by Eswaran and Kotwal. For identical outside options, as we have here, the optimal share will be exactly equal to one half.

2.1 Equilibrium tenure choice

From the landowners perspective, any of the three tenure relationships are available. They will choose the relationship that provides them the largest return. Comparing R^{FW}, R^{FR}, and R^{SH}, the optimal choice will depend on the parameters of the production function. In particular, the importance of supervision (ϵ), management (δ), and the productivity adjustments (γ_T and γ_N) will dictate the outcome.

Looking first at an extreme situation, one can see that if $\epsilon = 0$ and there are no supervision issues, then the FW tenure system is always best from the landlords perspective. Their inefficiency in supervision is immaterial, and the best option is to perform the management and supervision themselves while hiring in physical labor.

If there are no inefficiencies, or $\gamma_T = \gamma_N = 1$, then the fixed wage contract is also optimal, as there is no inefficiency loss from doing supervision by the landowner and their return is highest by undertaking the activity by themselves.

More generally, we can examine what will be chosen by a landlord given the productivity distortions present in the different systems. First, the fixed wage contract will be chosen when $R^{\mathrm{FW}} > R^{\mathrm{SH}}$, which will occur when

$$\gamma_N^{\epsilon\beta} > \frac{1-\beta+(1-\phi^*)\epsilon\beta-\phi^*\delta}{1-\beta+\epsilon\beta}\phi^{*\epsilon\beta}(1-\phi)^{*\delta} \equiv \hat{\gamma}_N^{\epsilon\beta} \tag{12}$$

or if the productivity distortion due to the landowners performing supervision is not too bad. If the loss of productivity from the fixed wage contract is large (i.e., γ_N is small), then the landowner is better off taking a smaller share of a larger output under sharecropping.

Similarly, fixed rent contracts will be preferred to sharecropping when

$$\gamma_T^{\delta} > \frac{1-\beta+(1-\phi^*)\epsilon\beta-\phi^*\delta}{1-\beta-\delta}\phi^{*\epsilon\beta}(1-\phi)^{*\delta} \equiv \hat{\gamma}_T^{\delta} \tag{13}$$

for a similar consideration, only now with respect to the distortion to output from tenants performing the management function. Finally, fixed rent contracts will be preferred to fixed wage contracts when

$$\gamma_T^{\delta} > \frac{1-\beta+\epsilon\beta}{1-\beta-\delta}\gamma_N^{\epsilon\beta} \tag{14}$$

which depends on the relative size of the productivity distortions in the two tenure systems.

The situation is summarized in Fig. 1, which plots the optimal choice given the values of γ_T^{δ} and $\gamma_N^{\epsilon\beta}$. As can be seen, only when both types of distortions are severe will sharecropping be chosen as the outcome. Outside of that region, the optimal choice depends on the relative size of the distortions, although note that the fixed wage contract is preferred even when both distortions are equal to one, as discussed above. The point Z is the point at which all three tenure

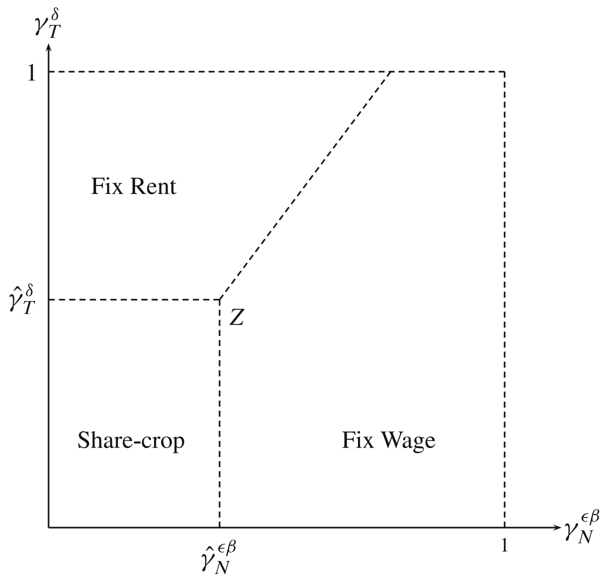

Fig. 1 Optimal tenure structure. Note: The *figure* illustrates the optimal choice of tenure system given the productivity distortion affecting landowners, $\gamma_N^{\epsilon\beta}$, and the distortion affecting tenants, γ_T^δ. The intersection Z is the point at which all three tenure systems yield identical returns to landowners. The cutoff values of $\hat{\gamma}_N^{\epsilon\beta}$ and $\hat{\gamma}_T^\delta$ are defined in the text

systems yield identical outcomes for the landowners. Note, though, that at this point it is not the case that output is identical under each system.

In the analysis that follows, I will concentrate primarily on the point Z, comparing the long-run outcomes under each of the three different tenure regimes. The advantage of looking at this single point is that the only thing that changes is the tenure choice, while all the productivity distortions remain fixed across the systems.

3 Tenure and population structure

The prior section allows us to characterize the situations in which different tenure regimes are selected. What are the implications of the tenure decision on long-run population? To answer this, I examine a simple unified growth model based on the work of Strulik and Weisdorf (2008). In the model, fertility is determined by the relative price of food and human capital accumulation is abstracted from completely. There are therefore not distinct regimes, as in Galor and Weil (2000), but the model still demonstrates dynamics that include relative stagnation followed by a period of rapid development and fast population growth before settling into a long-run equilibrium of low population growth and sustained increases in income per capita.

The usefulness of this model is that it very clearly highlights the role that labor's share in agricultural output plays in development, as discussed in Vollrath (2010). Regardless of the source of long-run development—

institutional improvement, technology, human capital accumulation—the labor share influences how responsive the economy is to these changes.

3.1 Individual optimization

Utility of the L one-period lived individuals is described, as in Weisdorf (2008) by a quasi-linear function

$$U = c + \theta \ln(n) \tag{15}$$

where c is the consumption of non-agricultural goods and n is the number of children. Adults do not consume food directly (one can assume that their food requirements were provided by their parents) but must purchase agricultural goods in order to produce children. The budget constraint is

$$I = c + p\bar{a}n \tag{16}$$

where I is income, p is the relative price of agricultural goods, and $\bar{a}$ is the food requirement of a child.

The optimal choice of children is, given the quasi-linear structure, independent of income,

$$n^* = \frac{\theta}{p\bar{a}}. \tag{17}$$

Changes in the relative price will drive changes in fertility over time. Anything that drives up agricultural productivity will drive down the price, and this will raise fertility.

Note that because there is no income effect, every individual has the same solution for fertility, regardless of whether they are a landowner or a tenant. This alleviates the need to track the exact distribution of land.

3.2 Production and labor market equilibrium

As mentioned in the previous section, there are N landowners holding X/N units of land, each operating with a production technology as in Eq. 1. The farms sell their output competitively, so each farm solves the problem of how to organize production in an identical manner, and the actual distribution of land is again irrelevant. We can thus use Eq. 1 as the aggregate production function for agriculture.

As mentioned in the section on tenure relationships, agricultural laborers and landowners have an outside option, which is working in the non-agricultural sector. This sector is assumed to operate with a technology linear in labor, so that $Y_M = wL_M$, and the marginal value of labor in that sector is w. In terms of the previous section, the outside option W is equal to w/p.

Assuming that labor effort is perfectly mobile between sectors, it must be that the return to a tenant in the agricultural sector is equal to w.[7] One can write this in a general form as

$$\frac{w}{p} = \mu \frac{Y_A}{L_A} \tag{18}$$

where μ is the fraction of total agricultural output that is earned by an agricultural tenant and L_A is the total number of tenants engaged in that sector. In the fixed wage system, L_A thus represents only the amount of physical labor, while in the fixed rent system, L_A represents physical labor plus management and supervision. Regardless, L_A is the total amount of labor provided by tenants in the agricultural sector.

A final condition is that total agricultural production must be equal to agricultural demand, which implies that

$$Y_A = L\bar{a}n \tag{19}$$

and this can be used with the optimal fertility decision in Eq. 17 and the equilibrium labor condition in Eq. 18 to solve for the equilibrium.

The outcome is that

$$L_A = \frac{\theta\mu}{w} L \tag{20}$$

which has several important features. First, agricultural productivity (A) has no influence on the number of tenants in the agricultural sector. Any increase in productivity lowers the price of fertility, which raises the number of children, and this immediately and perfectly offsets the change in productivity. If one allowed for demand for agricultural goods by adults, there would be short-run effects of productivity on the number of tenants, but in the long run, population effects would again eliminate the effect.

Secondly, note that the fraction of output going to agricultural labor, μ, drives the number of tenants. This is the first avenue through which tenure relationships will influence long-run outcomes. A choice of a tenure system that has a large fraction of output going to tenants (fixed rents, perhaps) will drive up the share of people engaged in that sector.[8]

Using Eq. 19, we know that $n = Y_A/(L\bar{a})$. Output will depend on the tenure decision made, so consider the fixed wage system first. Given Eq. 4, this means that

$$n^{\text{FW}} = \frac{Y_A^{\text{FW}}}{\bar{a}L} = \frac{\gamma_N^{\epsilon\beta}\hat{Y}_A}{\bar{a}L}. \tag{21}$$

[7] This equilibrium condition is identical for landowners, who recall are able to provide their labor as tenants as well. The difference between non-owners and owners is that owners have additional income depending on the tenure system. The marginal condition relating the return to tenancy and the outside option, though, is identical.

[8] Note that while L_A captures the number of tenants, it does not necessarily capture the total amount of labor (physical plus supervision plus management) engaged in agriculture.

Referring back to the definition of $\hat{Y}_A$ from Eq. 3, we can see that it depends on $W = w/p$. From Eq. 18, we know how to determine w/p and note that this depends on μ, the share of output going to tenants. For the fixed wage system, $\mu = (1-\epsilon)\beta$. Putting this all together, one can solve for

$$n^{\mathrm{FW}} = \frac{\gamma_N^{\epsilon\beta} A\Omega}{\bar{a}} \left(\frac{(1-\epsilon)\beta\theta}{w}\right)^{\beta+\delta} \left(\frac{X}{L}\right)^{1-\beta-\delta} \tag{22}$$

$$\Omega = \frac{\delta^\delta (\epsilon\beta)^{\epsilon\beta} (\beta - \epsilon\beta)^{(1-\epsilon)\beta}}{(\beta+\delta)^{\beta+\delta}} \tag{23}$$

which displays the classic Malthusian result that fertility is declining with the size of the population, given the fixed factor X. Note as well that as w, the marginal product of non-agricultural work, goes up fertility falls. This is the relative price effect at work, as increasing productivity in non-agriculture makes food relatively more expensive and therefore so is fertility.

Similar analysis for both fixed rent and sharecropping reveals that

$$n^{\mathrm{FR}} = \frac{\gamma_T^{\delta} A\Omega}{\bar{a}} \left(\frac{(\beta+\delta)\theta}{w}\right)^{\beta+\delta} \left(\frac{X}{L}\right)^{1-\beta-\delta} \tag{24}$$

and

$$n^{\mathrm{SH}} = \frac{\phi^{\epsilon\beta}(1-\phi)^{\delta} A\Omega}{\bar{a}} \left(\frac{(\beta - (1-\phi^*)\epsilon\beta + \phi^*\delta)\theta}{w}\right)^{\beta+\delta} \left(\frac{X}{L}\right)^{1-\beta-\delta} \tag{25}$$

which have the same basic properties as n^{FW}. Note, though, that there are several differences related to the productivity distortions and the share of output that is paid to labor.

Rather than look directly at the equilibrium fertility levels, it will be clearer to look at relative fertility levels. Take the ratio $n^{\mathrm{FW}}/n^{\mathrm{FR}}$ and you have

$$\frac{n^{\mathrm{FW}}}{n^{\mathrm{FR}}} = \frac{\gamma_N^{\epsilon\beta}}{\gamma_T^{\delta}} \left(\frac{(1-\epsilon)\beta}{\beta+\delta}\right)^{\beta+\delta} \tag{26}$$

which shows that fertility will differ to the extent that the productivity distortions differ and the tenants share in output differs. At this point, focusing on point Z in Fig. 1 is useful. Recall that at this point, all three tenure systems are equally lucrative to a landowner. It must be that

$$\frac{n^{\mathrm{FW}}}{n^{\mathrm{FR}}} = \frac{1-\beta-\delta}{1-\beta+\epsilon\beta} \left(\frac{(1-\epsilon)\beta}{\beta+\delta}\right)^{\beta+\delta} < 1 \tag{27}$$

given that $(1-\beta-\delta)\gamma_T^{\delta} = (1-\beta+\epsilon\beta)\gamma_N^{\epsilon\beta}$ at point Z. Both fractions in this expression are less than 1. It must be the case that $n^{\mathrm{FW}} < n^{\mathrm{FR}}$, or simply choosing a fixed wage system over a fixed rent system will lower fertility rates. The reason for this is that the fixed wage system, by raising the share of output earned by landowners, lowers the share earned by tenants. Thus, the returns to working in agriculture are lower and fewer individuals want to work there. To achieve equilibrium, agricultural prices must be higher and this lowers fertility.

Thus, the choice of fixed wage over fixed rent will lead to lower population growth.

An important point is that the productivity differences between tenure systems (the ratio of $\gamma_N^{\epsilon\beta}$ to γ_T^{δ}) is not the only thing driving fixed wage fertility lower than fixed rent fertility. Looking back at Eq. 26, one can see that even if these productivity adjustments are identical, it will still be the case that the differential share of output drives $n^{\mathrm{FW}} < n^{\mathrm{FR}}$. It is in fact possible for fixed wage productivity to be higher (which lowers food prices and raises fertility) and yet for fertility to be lower than in the fixed rent situation because of the difference in output shares.

A similar analysis can be done with respect to sharecropping, again assuming that the productivity distortions are such that the economy is at point Z. Recall, though, that tenants share of output under sharecropping can be thought of as an intermediate case lying in-between the fixed wage ($\phi = 0$) and fixed rent ($\phi = 1$) systems. Because of this, it will be the case that

$$n^{\mathrm{FW}} < n^{\mathrm{SH}} < n^{\mathrm{FR}} \tag{28}$$

at the point where all three tenure systems are equivalent in return to the landowner, point Z.

If the economy is *not* at this specific point, then it makes no sense to compare fertility under different tenure systems because only one system will be chosen. Comparing two different points in the diagram and therefore different tenure systems, the difference in fertility will depend not only the tenant's share of output but on the actual productivity distortions that hold. It's quite possible that a fixed rent system could have lower fertility than a fixed wage system if the ratio of productivity distortions were dramatic enough. However, the result in Eq. 28 shows us that, holding everything constant, fertility is the lowest in a fixed wage system.

3.3 Malthusian implications

Given the static differences in fertility among the tenure systems, there are several long-run implications. Let population evolve according to

$$L_{t+1} = n_t L_t \tag{29}$$

where n_t is the fertility rate determined in period t given land, X, the population at time t, L_t, the level of wages, w_t, and agricultural productivity, A_t.

Without any changes in productivity, the negative relationship of n_t to L_t, regardless of tenure system, will result in a Malthusian steady state with a fixed population size. Solving for the population sizes that set $n^{\mathrm{FW}} = 1$ and $n^{\mathrm{FR}} = 1$ using Eqs. 23 and 24, respectively, one can find the ratio

$$\frac{L^{*\mathrm{FW}}}{L^{*\mathrm{FR}}} = \frac{1-\beta-\delta}{1-\beta+\epsilon\beta}\left(\frac{(1-\epsilon)\beta}{\beta+\delta}\right)^{\tau} < 1 \tag{30}$$

where $\tau = (\beta+\delta)/(1-\beta-\delta)$. As expected, given the results regarding fertility, the steady-state population size is smaller with a fixed wage system when we assume the economy is at the point Z where tenure systems are equivalent in returns. This is true even holding X constant, so what we can see is that fixed rent systems will result in higher population densities than fixed wage systems. A similar argument as above regarding sharecropping shows that

$$L^{*\mathrm{FW}} < L^{*\mathrm{SH}} < L^{*\mathrm{FR}} \tag{31}$$

in steady state. The larger the share of output that is earned by tenants, the larger will be the size of the population as this induces more people to work in agriculture, driving down the price of food and driving up fertility.

3.4 Inequality

To this point, the actual distribution of land across owners has not been explicitly discussed. The assumption has been that land is sufficiently widespread so that interior solutions are the result of the optimization problem in each tenure system. In other words, the optimal amount of management plus supervision effort is less than one unit of time.

What happens if this is not the case? Consider a landowner with a very large holding. In this case, the fixed wage contract is less lucrative as the owner can only provide one unit of time total to supervision and management even though the optimal amount, if unconstrained, would be more. Compare this to the fixed rent contract. Here, the landowner can subdivide his holding up into several small parcels and rent them out to multiple tenants, each of whom can provide an amount of supervision and management that is optimal.

When land is concentrated into a small number of large holdings, this makes fixed wage contracts less attractive. In terms of the earlier notation, it is equivalent to raising the cutoff value $\hat{\gamma}^{\epsilon\beta}$. The point Z in Fig. 1 shifts to the right. This means that sharecropping and fixed rent contracts will be more prevalent. Thus, given the prior results regarding fertility, an increase in land inequality will, ceteris paribus, increase fertility as it makes fixed rent contracts more likely.

4 Implications for growth

The previous section shows that the choice of land tenure system will have an effect on fertility rates and long-run population size. Here I discuss the possible ramifications of this for long-run growth. Intuitively, the effect of land tenure, by acting on fertility rates, will influence growth, but this will depend on the relative importance of accumulation and innovation. Specifically, higher fertility reduces long-run income per capita if accumulation is what matters, as in a typical Solow model. However, if scale effects are prevalent for innovation, then higher fertility may actually raise long-run growth rates.

4.1 Accumulation

Consider first the effects on the accumulation of productive capital. A modification of the individual utility function to

$$U = \frac{c_1^{\eta} c_2^{1-\eta}}{\eta^{\eta}(1-\eta)^{1-\eta}} + \theta \ln(n) \tag{32}$$

alters the earlier specification by allowing for consumption over two periods of an individuals life. There will thus be a savings motive, and this will be the source of capital in an overlapping generations setting.

Let individual income be I_t, and their budget constraint is

$$I_t = c_{1t} + \frac{c_{2,t+1}}{1+r_{t+1}} + p\bar{a}n_t. \tag{33}$$

Optimizing utility with respect to this budget yields the following outcomes

$$n_t = \frac{\theta}{p\bar{a}} \tag{34}$$

$$s_t = (1-\eta)(I_t - \theta) \tag{35}$$

which shows that fertility is determined in a fashion similar to before and savings are a fraction $(1-\eta)$ of the income remaining after children's food is purchased.

An important aspect of s_t is that it is linear in income, and therefore, the exact distribution of income across individuals does not matter. Let y_{1t} be the income per worker of the young generation. Capital then accumulates according to

$$k_{t+1} = \frac{(1-\eta)(y_{1t} - \theta)}{1+n_t} \tag{36}$$

where k_{t+1} is capital per worker in period $t+1$.

To determine income per worker in period t requires more information on the non-agricultural sector. In the prior section, it was presumed that this sector was linear in labor with a productivity terms of w. Here we allow for capital to be used in non-agricultural production so that

$$Y_{Mt} = BK_t^{\alpha} L_{Mt}^{1-\alpha} \tag{37}$$

where B is a productivity term, K_t is the aggregate capital stock, and L_{Mt} is the number of workers in the non-agricultural sector.

Now we will assume that young workers earn all the returns to labor as well as the returns to land.[9] Their income per-capita is therefore

$$y_{1t} = p_t \frac{Y_{At}}{L_t} + (1-\alpha)\frac{Y_{Mt}}{L_t} \tag{38}$$

[9]This simplifies the analysis without making any qualitative changes.

where the first term captures the fact that the L_t young individuals earn all of the income from the agricultural sector and the second captures that they earn the $(1-\alpha)$ share of non-agricultural output for their labor.

From Eqs. 17 and 19, as well as Eq. 37, we can simplify this to

$$y_{1t} = \theta + (1-\alpha)Bk_t^{\alpha}\left(\frac{L_{Mt}}{L_t}\right)^{1-\alpha} \tag{39}$$

which implies that capital accumulation from Eq. 36 can be written as

$$k_{t+1} = \frac{(1-\eta)(1-\alpha)Bk_t^{\alpha}\left(\frac{L_{Mt}}{L_t}\right)^{1-\alpha}}{1+n_t} \tag{40}$$

and this has a typical OLG formulation, modified by the fact that the share of labor engaged in manufacturing L_{Mt}/L_t is relevant to accumulation.

How does land tenure influence this relationship? As established in Eq. 28, fertility differs based on the choice of tenure. Therefore, we can establish that

$$k_{t+1}^{\text{FW}} > k_{t+1}^{\text{SH}} > k_{t+1}^{\text{FR}} \tag{41}$$

given k_t.[10] Given Eq. 41, it follows that the steady-state level of capital is the highest in a fixed wage system because it allows for the lowest fertility level. Fixed rent will induce a smaller steady state as the economy produces food for a lower price, and therefore, fertility remains relatively high. So to the extent that growth depends on capital accumulation, the tenure system that produces the lowest fertility rate should end up the richest in steady state.

This provides one possible explanation for the correlation of land inequality and levels of per capita income, as in Easterly (2007). As land inequality increases, recall that this will push the economy toward the fixed rent or sharecropping tenure systems. These, by raising the share of output earned by tenants, lower the price of food and increase fertility. With accumulation, then, economies with high land inequality will end up with lower output per capita. The inequality/output connection does not necessarily have to operate through political economy considerations, which the work of Binswanger and Deininger (1997), Engerman and Sokoloff (1997), and Galor et al. (2009) document and describe.

The reduced form findings of Easterly do not provide information on exactly what channels link land inequality to lower development. It seems likely that the detrimental effect of land inequality on policy combines with the effect on fertility described in this paper to produce the overall relationship, as neither precludes the other. The model presented here suggests that if one could control for the political influence of landowners, a negative relationship should persist between land inequality and development because of the fertility effect.

[10] Note that because labor moves freely between sectors, L_{Mt}/L_t is the optimal allocation of labor to manufacturing. By the envelope theorem, we do not need to take into account the effect of a change in fertility on L_{Mt}/L_t.

Further empirical work along these lines could provide information on the relative importance of the fertility effect versus the political economy effect.

4.2 Innovation

The prior section did not allow for any technological progress, only showing that accumulation is slowed down by higher population growth. Is there a way in which the tenure system will interact with innovation to actually change steady-state growth rates?

Given the difference between tenure systems in fertility and population size, any effect on innovation would likely arise when scale becomes relevant to profits. A simple way of examining this can be found in Jones (2003, 2005). Let the growth of non-agricultural productivity be

$$B_{t+1} - B_t = \omega L_{St}^{\lambda} B_t^{\epsilon} \tag{42}$$

where $\omega > 0$ is a scaling parameter, while $0 < \lambda \leq 1$ and $\epsilon < 1$ dictate the nature of technological progress.[11] L_{St} is the number of scientists or researchers engaged in increasing productivity at time t. This formulation allows for knowledge spillovers ($\epsilon > 0$) or fishing out ($\epsilon < 0$). The parameter $\lambda < 1$ implies that there is some congestion or duplication involved in innovation.

The growth rate of productivity is

$$\frac{\Delta B_{t+1}}{B_t} = \omega \frac{L_{St}^{\lambda}}{B_t^{1-\epsilon}} \tag{43}$$

and in steady state L_{St} and B_t would have to grow at the same rate. This implies that

$$\frac{\Delta B_{t+1}}{B_t} = \frac{\lambda}{1-\epsilon} \frac{\Delta L_{S,t+1}}{L_{St}} \tag{44}$$

and along a balanced growth path it must be that L_{St} is growing at the same rate as population. If not, eventually scientists will make up 100% of the population and no production will take place, or they will make up 0% of the population and growth will be zero. These conditions have to hold in steady state regardless of the actual micro-foundations of the research sector.

Applying this balanced growth condition, in steady state, we have that

$$\frac{\Delta B_{t+1}}{B_t} = \frac{\lambda}{1-\epsilon} n_t \tag{45}$$

which says that productivity growth in non-agriculture is proportional to the growth rate of population. In this case, higher fertility is clearly a positive for growth. Therefore, a land tenure system such as fixed rent that allows for higher fertility will result in higher long-run growth. Fixed wage contracts, with

[11] I focus here on non-agricultural productivity because this will drive output per capita in the long run. Increases in agricultural productivity will only increase the long-run size of population.

lower fertility, do not produce as large a population, and therefore, the scale of the economy is smaller and productivity growth is slower.

Even if capital accumulation is a part of growth, the conditions presented here hold. In other words, innovation is able to overcome the decreasing returns to capital and the drag of high fertility on growth through accumulation is muted. The value of λ dictates the power of this effect. As λ goes to zero, productivity growth no longer depends on the scale of the population. In this case, greater fertility cannot produce higher growth and long-run productivity growth is equal to 0.

5 Conclusion

The variety observed in different agricultural settings has made land tenure relationships a subject of interest to economists for a very long time. The recent exploration of Malthusian population models and their implications for long-run growth has not dealt with tenure despite the central importance of the agricultural sector in these models.

This paper showed that one can incorporate tenure systems into a simple model of long-run growth. The result is that there are differences in fertility rates and the Malthusian steady-state population based on the type of tenure system used. Fixed rent systems, by allocating a larger fraction of agricultural output to tenants, encourages more tenants to enter that sector and drives down food prices, raising fertility. Fixed wage systems have the opposite effect due to the lower share gained by tenants, and sharecropping is an intermediate case.

The implication of this for growth in the long run depends on whether scale effects are at work. If innovation increases with the number of researchers working or with the size of the market, then the higher fertility of fixed rent systems will generate higher output per capita in the long run. On the other hand, if accumulation of capital with decreasing returns is relevant, then fixed wage systems that lower fertility will be the best for output per capita.

Most models of long-run population and growth assume no property rights over land and so allow tenants to earn their entire average product. In purely theoretical terms, this may not be problematic when examining the sources of take-off to sustained growth. However, if one is trying to calibrate models like this to do an accounting of the sources of growth, then the results here suggest that one should account for the tenure structure so that fertility rates are correctly modeled.

The model presented here also provides a way of thinking about the negative relationship between land inequality and overall development levels. To the extent that family farming is a form of fixed wage tenure and development levels depend upon accumulation, then the result that economies with a large proportion of family farms are richer on a per capita basis makes sense given the lower fertility rates. This offers an alternative, but complementary, explanation alongside those that focus upon the political economy of land distribution and its influence on policy.

References

Binswanger H, Deininger K (1997) Explaining agricultural and agrarian policies in developing countries. J Econ Lit 35(4):1958–2005
Binswanger H, Deininger K, Feder G (1995) Power, distortions, revolt, and reform in agricultural land relations. In: Behrman J, Srinivasan T (eds) Handbook of development economics. Elsevier Science, Amsterdam, pp 2659–2772
Boserup E (1965) The conditions of agricultural growth. Earthscan, London
Caselli F (2005) Accounting for cross-country income differences. In: Aghion P, Durlauf S (eds) Handbook of economic growth. Elsevier Science, Amsterdam, pp 679–741
Cheung, S (1969) The theory of share tenancy. University of Chicago Press, Chicago
Conning, J (2002) Latifundia economics. Working paper 02/1, Hunter College Department of Economics
Doepke, M (2004) Accounting for fertility decline during the transition to growth. J Econ Growth 9(3):347–383
Easterly, W (2007) Inequality does cause underdevelopment. J Dev Econ 84(2):755–776
Engerman S, Sokoloff K (1997) Factor endowments, institutions, and differential growth paths among new world economies. In: Haber S (ed) How Latin America fell behind. Stanford University Press, Stanford, pp 260–304
Eswaran M, Kotwal A (1985) A theory of contractual structure in agriculture. Am Econ Rev 75(1):162–177
Galor O (2005) From stagnation to growth: unified growth theory. In: Aghion P, Durlauf S (eds) Handbook of economic growth. Elsevier Science, Amsterdam, pp 171–293
Galor O, Moav O (2002) Natural selection and the origin of economic growth. Q J Econ 117(4):1133–1191
Galor O, Moav O, Vollrath D (2009) Inequality in landownership, the emergence of human-capital promoting institutions, and the great divergence. Rev Econ Stud 76(1):143–179
Galor O, Mountford A (2008) Trading population for productivity: theory and evidence. Rev Econ Stud 75(4):1143–1179
Galor O, Weil D (1999) From Malthusian stagnation to modern growth. Am Econ Rev Pap Proc 89(2):150–154
Galor O, Weil D (2000) Population, technology, and growth: from Malthusian stagnation to the demographic transition and beyond. Am Econ Rev 90(4):806–828
Gollin D, Parente S, Rogerson R (2007) The food problem and the evolution of international income levels. J Monet Econ 54(4):1230–1255
Hall R, Jones CI (1999) Why do some countries produce so much more output per worker than others? Q J Econ 114(1):83–116
Hansen GD, Prescott EC (2002) Malthus to Solow. Am Econ Rev 92(4):1205–1217
Jones CI (2001) Was an industrial revolution inevitable? Economic growth over the very long run. Adv Macroecon 1(2):1–43
Jones CI (2003) Population and ideas: a theory of endogenous growth. In: Agion P, Frydman R, Stiglitz J, Woodford M (eds) Knowledge, information, and expectations in modern macroeconomics: in honor of Edmund S. Phelps. Princeton University Press, Princeton, pp 498–521
Jones CI (2005) Growth and ideas. In: Aghion P, Durlauf S (eds) Handbook of economic growth. Elsevier Science, Amsterdam, pp 1063–1111
Klenow P, Rodriguez-Clare A (1997) The neoclassical revival in growth economics: has it gone too far? In: Bernanke B, Rotemberg J (eds) NBER macroeconomics annual. MIT, Cambridge, pp 73–114
Kogel T, Prskawetz A (2001) Agricultural productivity growth and escape from the Malthusian regime. J Econ Growth 6(4):337–357
Kremer M (1993) Population growth and technological change: 1000000 B.C. to 1990. Q J Econ 108(3):681–716

Marshall A (1920) Principles of economics, 8th edn. Macmillan, London
Moav O (2005) Cheap children and the persistence of poverty. Econ J 115(500):88–110
Newberry DMG (1977) Risk-sharing, sharecropping, and uncertain labour markets. Rev Econ Stud 44(3):585–594
Otsuka K, Chuma H, Hayami Y (1992) Land and labor contracts in agrarian economies: theories and fats. J Econ Lit 30(4):1965–2018
Restuccia D, Yang D, Zhu X (2008) Agriculture and aggregate productivity: a quantitative cross-country analysis. J Monet Econ 55(2):234–250
Stiglitz J (1974) Incentives and risks in sharecropping. Rev Econ Stud 41(2):219–255
Strulik H, Weisdorf J (2008) Population, food, and knowledge: a simple unified growth theory. J Econ Growth 13(3):195–216
Timmer CP (1988) The agricultural transformation. In: Chenery H, Srinivasan TN (eds) Handbook of development economics, vol I. Elsevier Science, Amsterdam, pp 275–331
Vollrath D (2009) The dual economy in long-run development. J Econ Growth 14(4):287–312
Vollrath D (2010) The agricultural basis of comparative development. University of Houston Working Paper
Weisdorf J (2008) Malthus revisited: fertility decision-making based on quasi-linear preferences. Econ Lett 99(1):127–130