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GERONTOCRACY REVISITED. UNILATERAL TRANSFER TO THE YOUNG MAY BENEFIT THE MIDDLE-AGED

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Abstract

It has been argued that in the absence of altruism, intergenerational transfers can survive only if the old are net recipients. I prove that this need not hold in an over-lapping generations model with a fixed factor. For example, the middle-aged owning land may gain by providing public education even when they cannot tax the young. This requires that labor is not mobile. Furthermore, establishing public education may benefit only the generation which pays for education twice, first for itself and then for the next generation.

Keywords: Intergenerational goods; education; land; gerontocracy.

JEL Classification: C72; D72; I28; H77.

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1. Introduction

Conventional wisdom argues that in the absence of altruism, an older generation may pay for the education of the following generation only if it can reap gains through social security benefits or other forms of public expenditure. Konrad (1995) formalizes this argument by showing that even a gerontocracy controlled by the old may find it optimal to finance education for the young in order to boost social security tax revenue. Rangel (2000) developed a theory of intergenerational exchange for selfish generations. He distinguished between intergenerational goods which are provided by the middle-aged to the young and those which are provided by the middle-aged to the old. He shows that a pay-as-you-go system may be self-sustainable if it generates a positive surplus for each participating generation. However, providing education for the younger generation is not sustainable without linking it into sufficiently big transfers to the old. If the surplus generated by the pay-as-you-go system and other goods provided by the middle-aged to the old does not exceed the costs of providing the education and other intergenerational goods that benefit the young, then the middle-aged would prefer to repudiate such an intergenerational contract.

If pay-as-you-go social security system were the only mechanism allowing public provision of education to survive, then privatizing social security would eliminate public provision of education. In a world of credit constraints or non-insurable risks, this could have dire consequences for future growth and welfare. In a world with full certainty and no credit market constraints, we would expect an efficient level of private investment in human capi-

tal. However, there are market mechanisms which may encourage the middle-aged to finance education for the young even in the absence of social security taxes or any other public expenditures benefiting the old. If the middle-aged have a stake in the future and the value of that stake depends on future human capital, the middle-aged may voluntarily invest in the younger generation. Boldrin (1994) presented a closed economy model in which the working generation accumulates physical capital, physical capital and human capital being technologically complementary. When the young would otherwise make an inefficiently low educational investment, the middle-aged may collectively find it rational to invest in the human capital of the following generation in order to increase the value of their physical capital. Education provided for the young is essentially a public good benefiting all the middle-aged. Public provision of education is used to avoid free riding. Boldrin and Montes (2000) generalize this insight by arguing that pay-as-you-go social security system may encourage efficient human capital investment by increasing the stake that the current middle-aged generation has in future production.

My paper argues that there exists a market mechanism which may render investment in human capital of the following generation profitable even without any market failure, and with internationally mobile financial capital. This mechanism consists of market transactions of land.[1] Here land should be interpreted generally to incorporate all fixed factors used in production. The middle-aged may want to invest in the young in order to receive a better price for land when they sell it to the following generation. While Konrad (1995) recognizes

[1]Homburg (1991) demonstrates the importance of including land in the production function in a growth model. Intergenerational trade in land rules out dynamic inefficiency as well as Golden Rule growth.

this mechanism in the discussion, it is not included in his model. Furthermore, in Konrad's model, public provision of social capital is financed with taxes collected from the young later in the same period. In contrast, in this paper the middle-aged generation deciding on publicly provided education also finances it.

The introduction of land into an OLG framework generates the following new and surprising results. First of all, the middle-aged may want to provide public education even if the young would not face any credit market constraints, and could finance their education themselves. The old may voluntarily overinvest in the young even when they cannot tax any of the productivity increase. Secondly, it is possible that all welfare gains from establishing public education accrue to the generation which pays for education *twice*, once for itself and then for the subsequent generation. Numerical analysis suggest that all the following generations lose. This result is in marked contrast with the intuitive expectation that the generation establishing public education without being able to tax any of the benefits through a social security system would be made worse off. Thirdly, an intergenerational contract relying on a voluntary provision of a good for the next generation *may under certain conditions* be a bad equilibrium for the steady state generations.

Rangel's (2000) results suggest that voluntary intergenerational transfers may survive only if they produce a surplus for all participating generations. He also argues that the middle-aged would always repudiate even an efficient social contract under which they invest in the following generation without receiving any transfers back. According to Konrad (1995), there may be an overinvestment in social capital by the older generation. The older

generation chooses social capital investment to maximize tax revenue from the young net of investment costs. Cooley and Soares (1999) construct a model in which a pay-as-you-go system can be adopted as a voting equilibrium among generations in a closed economy. The middle-aged and old generations consider the contributions they have made as sunk costs. My paper differs from these earlier contributions in that resources are voluntarily transferred from an older to a younger generation without any transfers back from the younger to the older generations.

The paper is organized as follows. Section 2 presents the laissez-faire solution. There are no efficiency or welfare motivations for public investment, implying that the laissez-faire outcome is Pareto efficient. Section 3 analyzes the conditions under which the middle-aged prefer to finance education publicly. Game theoretically, the economy is depicted as a repeated game with overlapping generations of players in the spirit of Kandori (1991), Salant (1992), Smith (1992), Boldrin and Montes (2000) and Rangel (2000). As in Rangel (2000), the provision of education is assumed to rely on a trigger strategy. Each middle-aged generation assumes that if it would repudiate from providing public education, then all the following middle-aged generations would also repudiate, and the economy would end up in a laissez-faire equilibrium. Section 4 analyzes political decision-making when labor is mobile. Section 5 concludes.

2. Laissez-faire outcome

2.1. The model

There are three generations: the young, the middle-aged and the old. The young invest in education, the middle-aged work, and the old derive income from land ownership. There is perfect certainty and all individuals of each generation are identical. All individuals make their decisions in a decentralized manner. The mass of each generation (cohort) is normalized at unity and consists of a continuum of individuals, so that each individual behaves atomistically.

Production combines land and human capital supplied by the middle-aged. All individuals can borrow and lend internationally at a constant world interest rate. The time structure inside a period is as follows:

1. Production takes place. The middle-aged supply their labor inelastically.

2. The middle-aged receive their marginal product as their wage income, and the old receive the income accruing to land. The middle-aged pay back the loan that they have taken as young. The young take a loan.

3. The old sell land to the middle-aged. They pay back the loan taken (receive back the savings made) when they were the middle-aged. The middle-aged decide on their net saving for the old age.

4. The young complete their education and pay for it using the loan they have taken.

It is not essential to define at which point the young start investment in education. Furthermore, production may also continue during latter parts of the period. The results are also insensitive to a change in which the old would sell land to the middle-aged before

land receives its factor income. The timing of individual actions, except for consumption and saving decisions, is depicted in Figure 1. The timeline is divided into three periods corresponding to youth, middle age, and old age.

Figure 1

Production in period t, Y_t, is determined by a Cobb-Douglas function combining human capital in the economy in the respective period, H_t, and land. The amount of land is normalized at unity. Formally,

$$Y_t = H_t^{\alpha},$$

in which $\alpha, 0 < \alpha < 1$, is the elasticity of production with respect to human capital, and also the share of production accruing to human capital.

Human capital of a representative individual, h_t, is equal to H_t as cohort size is normalized at unity. Human capital of an individual in period t depends on that individual's educational investment in period $t-1$. Educational investment e consists of inputs whose price is normalized at unity. Production function of human capital is, dropping individual-specific subscript,

$$h_t = e_{t-1}^{\beta},$$

in which $0 < \beta < 1$ captures the assumption that the marginal productivity of educational inputs is diminishing.

The middle-aged have to wait for one period before they receive income from the ownership of land and the income from selling it to the following generation. The arbitrage requires that the return on the ownership of land equals the world interest rate, denoted by r. Therefore, the land value in period t, V_t, is determined by:

$$(1+r)V_t = (1-\alpha)H_{t+1}^{\alpha} + V_{t+1}. \tag{1}$$

2.2. Equilibrium under laissez-faire

Time indices are dropped, as in the steady-state equilibrium $e_t = e_{t+1} = e$ and therefore $H_t = H_{t+1} = H$ and $V_t = V_{t+1} = V$. The young individually choose their own educational investment. Each young individual takes the expected net return on human capital, denoted by ρ, as given. Educational investment e is chosen to maximize:

$$\max_{e} \left[\frac{e^{\beta}\rho}{1+r} - e \right],$$

with the first-order condition

$$\frac{\rho\beta e^{\beta-1}}{1+r} = 1. \tag{2}$$

The left-hand side tells the net present value of return on marginal educational investment, whereas the right-hand side is the marginal cost. As there are no borrowing con-

straints, investment is made in order to maximize net present value of wage income net of investment costs. Next, substitute

$$\rho = \alpha H^{\alpha-1} = \alpha h^{\alpha-1},$$

where $h = e^{\beta}$ into the first-order condition (2). This allows us to solve the individually optimal educational investment:

$$\widehat{e} = \left(\frac{\alpha\beta}{1+r}\right)^{\frac{1}{1-\alpha\beta}}. \tag{3}$$

Note that the ownership of land has no effect on educational choices. The reason for this is that for each individual, perfect international capital market allows to separate decisions of investment in education from the intertemporal allocation of consumption. In the steady-state equilibrium, the price of land is

$$V(\widehat{e}) = \frac{(1-\alpha)\widehat{e}^{\alpha\beta}}{r}. \tag{4}$$

3. Public provision of education

3.1 The setting of intergenerational game

Under public provision of education, steps 1, 2 and 3 inside a period are the same as in

the laissez-faire solution. The fourth step, however, reads now as:

4' The middle-aged vote on a lump-sum tax collected from themselves to purchase education for the young. The young voluntarily receive the education.

As all the middle-aged are identical, they agree on the lump-sum tax. The time structure is such that the middle-aged cannot commit to a given provision of human capital for the next generation before they purchase land from the old.[2] Other parts of the time structure could be changed without affecting the results as described in subsection 2.1. The timing of individual actions except for saving and consumption is depicted in Figure 2.

Figure 2

Denote the first period in which publicly provided education can take place by 0, and the lump-sum tax collected in period t by τ_t.[3] Lump-sum tax τ_t is equal to educational investment as there is no population growth. It is assumed that if public provision of education can be sustained in equilibrium, then there is an equilibrium tax rate $\widehat{\tau}$.[4] Starting from period $t = 0$, each middle-aged generation either deviates or adopts the following trigger strategy:

[2]It is enough to assume that the middle-aged cannot commit to not purchasing more education for the young than they have declared beforehand. As the price that the middle-aged pay for the land turns out to be increasing in expected future human capital, it would be never in the interest of the middle-aged to claim before buying the land that they would invest more in human capital than they would actually do.

[3]I have assumed that the possibility of publicly provided education becomes known only in the first period when it can be established after the middle-aged have bought the land. In that sense, the introduction of taxation technology is an unpredicted shock to the model.

[4]As there is no population growth or technological change, there is no reason to expect that the tax rate would change over time. In a growing economy, we would analyze an equilibrium path of tax rates over time. While this would make the analysis more cumbersome, it would not provide any additional insight.

$$\tau_t = \left\{ \begin{array}{c} \widehat{\tau} \text{ if } t = 0 \\ \widehat{\tau} \text{ if } \tau_0 = \tau_1 = ... = \tau_{t-1} = \widehat{\tau} \text{ and } t \geq 1 \\ 0 \text{ otherwise} \end{array} \right\}. \tag{5}$$

If $\tau_t \neq \widehat{\tau}$ and $\tau_t > 0$, then the economy reverts in the following period to the laissez-faire equilibrium in which each generation purchases its own education in a non-coordinated manner. Lump-sum tax is restricted to be non-negative. If the middle-aged choose $\tau_t = 0$, then the economy immediately reverts to private educational investments by the young.

3.2. Equilibrium with public education

Let us first assume that there exists a steady state equilibrium with publicly provided education. As cohort size is normalized at unity, human capital in the steady-state equilibrium with lump-sum tax $\widehat{\tau}$ is given by $\widehat{\tau}^{\beta}$. This allows to solve as the steady-state market price of land

$$V(\widehat{\tau}) = \frac{(1-\alpha)\widehat{\tau}^{\alpha\beta}}{r}.$$

When the initial generation decides on whether to switch to public education, it has already purchased land. Therefore, the price that it has paid for land is irrelevant for

the choice of educational policy. Public investment in education is chosen to maximize the discounted sum of rental income and sale revenue of land in the next period, net of investment cost. As $\widehat{\tau}$ can be sustained in equilibrium, the middle-aged generation of period 0 knows that future generations will choose the same level of taxation as they choose. Rental income in the following period is simply $(1-\alpha)\tau^{\alpha\beta}$. Therefore, τ is chosen to maximize

$$\max_{\tau}\left(\frac{(1-\alpha)\tau^{\alpha\beta}}{1+r}+\frac{(1-\alpha)\tau^{\alpha\beta}}{(1+r)r}-\tau\right), \tag{6}$$

giving as the optimal choice:

$$\widehat{\tau}=\left(\frac{(1-\alpha)\alpha\beta}{r}\right)^{\frac{1}{1-\alpha\beta}}. \tag{7}$$

The middle-aged of period 0 want to establish public provision of education instead of laissez-faire solution only if this increases their lifetime net income. A sufficient and necessary condition for this is derived in Appendix A. Appendix A proves also that this is a sufficient and necessary condition for the public provision to be sustainable in equilibrium. The results can be summarized as

Proposition 1. *The presence of land may alone motivate public provision of education, even when private investments would be efficient and there is no altruism. Education is provided publicly if and only if the interest rate satisfies* $r<\frac{(1-\alpha)(1-\alpha\beta)^{\frac{1-\alpha\beta}{\alpha\beta}}}{1-(1-\alpha)(1-\alpha\beta)^{\frac{1-\alpha\beta}{\alpha\beta}}}$.

Proof. See Appendix A.

It also holds that

Proposition 2. *Public provision of education leads to a bigger investment in education than in a decentralized solution.*

Proof. The land value is increasing in human capital. As the laissez-faire solution is always available, a necessary condition for the middle-aged to provide education publicly is that it increases human capital sufficiently to increase the present value of lifetime income of the middle-aged net of taxes. □

The land value plays a role equivalent to the trigger strategy's role in Rangel (2000). In Rangel's model, the trigger strategy relies on transfers from the younger to the older generations. In my model, there is no need for transfers from the young to the old. Instead, the trigger strategy relies on decentralized and voluntary market transactions. If a middle-aged generation deviates from the public provision of education to the following generation, then it would suffer a capital loss in the land value.

Numerical examples suggest that the internationally determined interest rate has to be very low to justify public provision of education.[5] This is not surprising as my results are derived using the extreme assumption that public provision does not offer any efficiency gains,

[5]For example, for $\alpha = \beta = \frac{1}{2}$ the condition is $r < \frac{27}{101}$. If this would be accrued over 20 years, yearly interest rate should be less than 1.2 per cent. With only a 10 year delay between investment cost and trade in land, a yearly interest rate would still have to be less than 2.4 per cent.

and that the middle-aged generation finances education entirely without being able to tax any of its benefits. Furthermore, assuming the Cobb-Douglas production function excluded the possibility that the share of production going to the land owners could be increased by increasing the stock of human capital, and there was no growth. Including a social security tax would increase the range of interest rates in which the middle-aged generation would find it optimal to finance education. Furthermore even without social security taxes, the middle-aged generation may resort to the less expensive strategy of subsidizing educational investment only partially. However, these modifications are not needed to prove that it *may* be in the interest of the older generations to engage in unilateral transfers to the younger generations.

The welfare effects of providing public education on future generations are not clear ex ante. On one hand, future generations are able to postpone the financing of education from youth to middle-age, thereby saving the interest payment on investment. On the other hand, the resulting level of educational investments is not efficient. Numerical analysis suggests that the establishment of public education lowers the utility of the current young and all future generations.[6] Therefore, there is no potential of intergenerational Pareto improvement through the establishment of public education. What is remarkable is that none of the steady

[6]Numerical analysis was carried out for all values of $\alpha \in [0.1, 0.9], \beta \in [0.1, 0.9], r \geq 0.05$ at the interval of 0.01. I first calculated the parameter combinations with which the middle-aged of period 0 would prefer to establish public provision of education. Then I compared the net present value of lifetime income for a steady state generation under the laissez-faire solution and under the public provision of education. Under very low interest rates, lump-sum taxes may exceed wages for the steady state generations. Even though it were interpreted that the model is not applicable with those values, there is still a range of interest rates in which it is profitable for the middle-aged to provide education for the young even though they cannot tax the young, and the steady state generations have a lower positive net lifetime income under public provision of education than under a laissez-faire equilibrium.

state generations has an incentive to abolish the system of public education once established as proved in Appendix A.

4. Equilibrium with mobile labor

In this section, I analyze the implications of labor mobility on education policy. While lump-sum taxes, proportional taxes and public resources per student were equivalent policy variables with a constant population, this equivalence no longer holds with migration. For example, constant educational resources per young person over time imply changes in tax burden of the middle-aged workers when there is migration. Lump-sum taxes would imply that the percentage of wage income paid in taxes would be different across native citizens and immigrants, if they have different endowment of human capital. Therefore, lump-sum taxation is no longer just a simplifying technical assumption that it was in the previous section. To capture the fact that taxes are typically levied on income, I therefore define public policy in this section as a choice of wage-tax rate τ_w.[7] In a steady state with a constant population over time, this would also imply constant educational resources per young person over time.

I have assumed that there are no migration costs, and that domestic and foreign human capital are perfect substitutes in production everywhere. Migration decisions take place at the beginning of the middle-age after education is completed. Migration decisions are

[7]Time index is dropped for simplicity.

made under perfect foresight, so that individuals correctly anticipate post-migration human capital in different regions and decisions that will be made concerning whether to provide education publicly. Migration decisions are made in order to maximize wage income net of taxes. Public policy affects migration decisions only through its effects on after-tax wage income. Arbitrage conditions imply that return on land ownership is the same everywhere, so that it does not play any role in migration decisions. The region analyzed is small in relation to the whole world and takes the after-tax return on human capital, $\widetilde{\rho}$, as given. The timing of individual actions except for saving and consumption in a laissez-faire region with private educational decisions is depicted in Figure 3.

Figure 3

With labor mobility, return on human capital in a laissez-faire economy is determined by

$$\widetilde{\rho} = \alpha H^{\alpha-1},$$

giving as post-migration human capital

$$H = \left(\frac{\alpha}{\widetilde{\rho}}\right)^{\frac{1}{1-\alpha}}.$$

With publicly provided education, the timing of individual actions except for saving and consumption is depicted in Figure 4.

Figure 4

With tax rate τ_w, after-tax return on human capital is determined by

$$\widetilde{\rho} = (1 - \tau_w)\alpha H^{\alpha-1},$$

giving as post-migration human capital

$$H(\tau_w) = \left(\frac{(1 - \tau_w)\alpha}{\widetilde{\rho}}\right)^{\frac{1}{1-\alpha}}. \tag{8}$$

Note that post-migration human capital is independent of human capital produced in the economy, regardless of whether such investments are chosen by individuals or through publicly provided education. This implies

Proposition 3. *With labor mobility, the middle-aged never provide public education with decentralized taxation.*

Proof. The land value depends on post-migration human capital. In the steady state it is given by $V(\tau_w) = [(1 - \alpha)H(\tau_w)^{\alpha}]/r$. (8) reveals that $\frac{\partial H(\tau_w)}{\partial \tau_w} < 0$, implying that post-migration human capital is the smaller the higher the tax rate to finance public education. This implies that establishing publicly provided education would lead both to a capital loss

in land value and also to a decrease in income due to taxes. Therefore, it is profitable for the middle-aged in each region to abolish publicly provided education. □

Proposition 3 does not require that all regions would be identical. A sufficient condition is that all regions take net return on human capital as given, and human capital is perfectly mobile. Regions may differ in population size, the amount of land, and even in production technologies. If regions are different, then the middle-aged in those regions receiving migration may gain from allowing international migration, whereas the middle-aged in other regions are likely to be hurt. In a world consisting of identical regions, a transition from no-migration equilibrium to free labor mobility has the following effects:

Proposition 4. *Allowing free mobility between identical regions which initially provide education publicly results in the abolishment of public education. The land owners at the time of liberalization lose as land values drop to a laissez-faire level. Steady-state production is decreased.*

Proof. By proposition 2, public education implies increased human capital investment. As liberalization eliminates public education, it lowers both steady-state production and land value. If the old have not yet sold land to the middle-aged when the liberalization takes place, they bear the full loss. If liberalization takes place after land has been sold, then the middle-aged bear the loss. The middle-aged lose even when liberalization takes place before they have provided education publicly, and can therefore save the taxes by abolishing public

education immediately. The reason for this is that if the net present value of the difference in land value would not exceed the cost of public education, then public provision would not be equilibrium, even without migration in the first place. □

5. Conclusion

In this paper, I demonstrated that the intergenerational trade in land may have many effects on the provision of intergenerational goods. In a model without land, Rangel (2000) proved that voluntary intergenerational transfers can survive only if they generate a positive surplus for the old. I show that if there is intergenerational trade in land, the middle-aged may voluntarily provide education for the young even when they do not receive any transfers. The provision of public education may be established solely in order to increase market value of land. Furthermore, the provision of public education may lead to excessive investment in human capital even when it does not change the actual share of production going to human capital.

Globalization may undermine public support for education in two different ways. First of all, labor mobility restricts redistribution between different groups, as demonstrated by Wildasin (1991) and many other authors. This paper shows that labor mobility eliminates the incentives for a middle-aged generation to provide education in order to increase the land value, as an increase in human capital would be diluted internationally. Secondly, this paper also suggests that international dispersion of the land ownership decreases national

incentives to provide education for the following generation even when labor is immobile. The smaller the share of land owned domestically, the less the middle-aged are prepared to pay in taxes in order to increase its market value.

While public provision of education turned out to be excessive in my simple model, it may play a beneficial role for younger generations in a more complex model. If there are externalities associated with education or if there are imperfect credit markets for the young or missing insurance markets for income risks associated with education, then public intervention may provide a Pareto improvement. Under those circumstances, the deterioration of public education may counterweight potential benefits of globalized labor markets. Furthermore, my model suggests that the ownership of land may play an important role in the political decision-making on intergenerational goods even when land is untaxed. The more widely the land ownership is distributed inside an economy, the wider the support for investment in the following generation. In a globalized economy, investing social security wealth in domestic market may be justified in order to provide incentives for the older generation to invest in the younger generation. Therefore, even a funded social security system might be able to provide incentives to public investment in the human capital of the following generation, provided that such social security funds are invested in domestic market, and labor mobility is sufficiently low.

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Appendix A. Proof of Proposition 1

I calculate first the payoff for a middle-aged generation from playing the equilibrium strategy. Then I calculate the payoff from deviation and show the condition under which no deviation from the equilibrium strategy is profitable.

The payoff from the assumed equilibrium strategy defined by (5) and (7) for the middle-aged generation is the same for all middle-aged generations as long as there has been no deviation, including the first generation which may provide education publicly.[8] Substituting (7) to (6) yields

$$\left(\frac{(1-\alpha)\alpha\beta}{r}\right)^{\frac{\alpha\beta}{1-\alpha\beta}} \frac{(1-\alpha)(1-\alpha\beta)}{r}. \tag{A.1}$$

[8]While the first generation turns out to be better off when public education is adopted, this difference follows from it having paid a lower price for land when publicly provided education was not yet available. All the following generations have to pay a higher land price if public education is established and maintained. As these trades take place in each period before the decision of lump-sum taxes is made, they do not enter the decision on taxes. Therefore, the first generation and all the following generations play the equilibrium strategy under the same conditions.

I analyze first a deviation to $\tau = 0$. This leads into the laissez-faire equilibrium. In the laissez-faire equilibrium, the middle-aged receive by (3) and (4)

$$\frac{(1-\alpha)\widehat{e}^{\alpha\beta}}{1+r} + \frac{V(\widehat{e})}{1+r} = \frac{(1-\alpha)}{r}\left(\frac{\alpha\beta}{1+r}\right)^{\frac{\alpha\beta}{1-\alpha\beta}}. \tag{A.2}$$

Next I analyze a deviation to any positive lump-sum tax which differs from the equilibrium strategy. Formally, I solve for an optimal τ_d when $\tau_d > 0, \tau_d \neq \widehat{\tau}$. By the trigger strategy, a deviation would imply that from the following period onwards, the economy would stay in a laissez-faire equilibrium. A deviation $\tau_d > 0$ is chosen to maximize

$$\max_{\tau_d}\left[\frac{(1-\alpha)\tau_d^{\alpha\beta}}{1+r} - \tau_d + \frac{V(\widehat{e})}{1+r}\right], \tag{A.3}$$

leading to the most profitable deviation subject to $\tau_d > 0$:

$$\tau_d = \left[\frac{(1-\alpha)\alpha\beta}{1+r}\right]^{\frac{1}{1-\alpha\beta}}. \tag{A.4}$$

It is easy to show that substituting (A.4) into (A.3) leads into a smaller value than (A.2). Therefore, the most profitable deviation is $\tau = 0$, implying an immediate reversion to the laissez-faire equilibrium. Thus, public provision is preferred if the net present value of income given by (A.1) exceeds the laissez-faire outcome given by (A.2). This condition yields

$$r < \frac{(1-\alpha)(1-\alpha\beta)^{\frac{1-\alpha\beta}{\alpha\beta}}}{1-(1-\alpha)(1-\alpha\beta)^{\frac{1-\alpha\beta}{\alpha\beta}}}. \tag{A.5}$$

Therefore, public education is established and sustained in equilibrium if and only if condition (A.5) is met.

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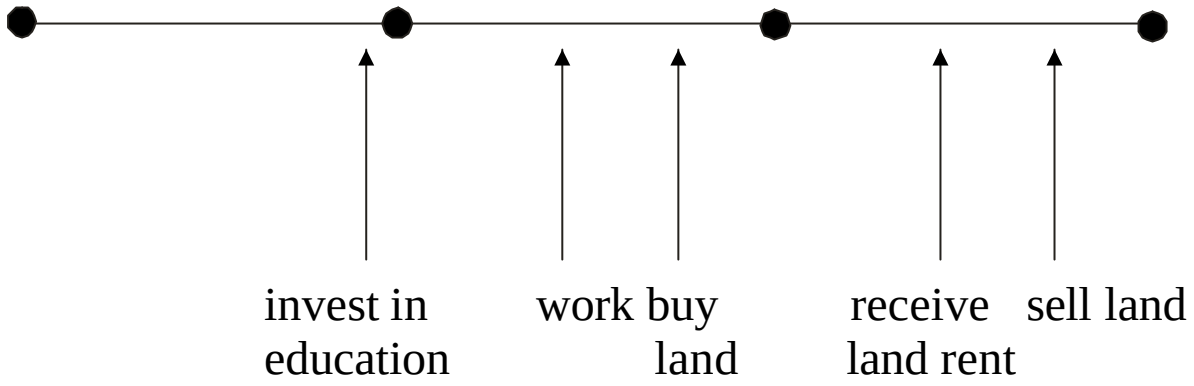

Figure 1. Timing with private education.

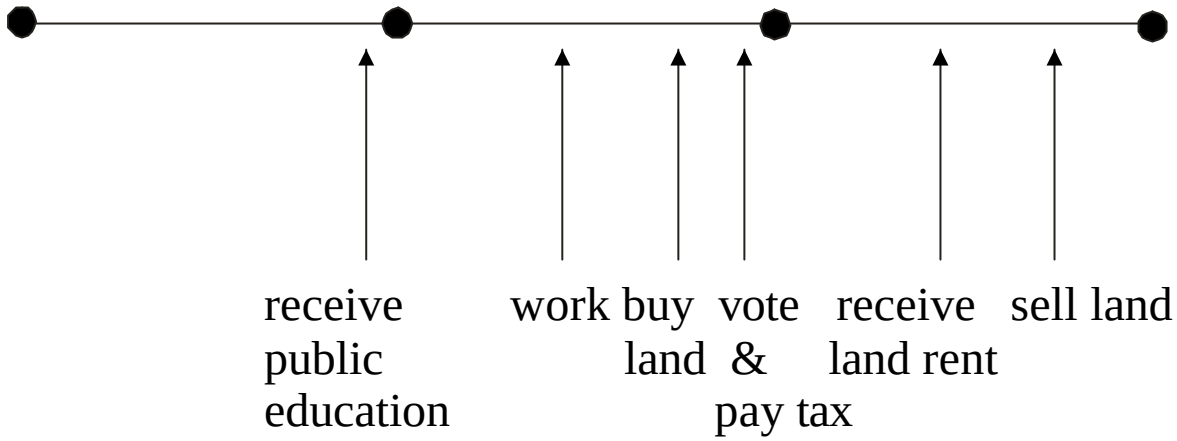

Figure 2. Timing with public education.

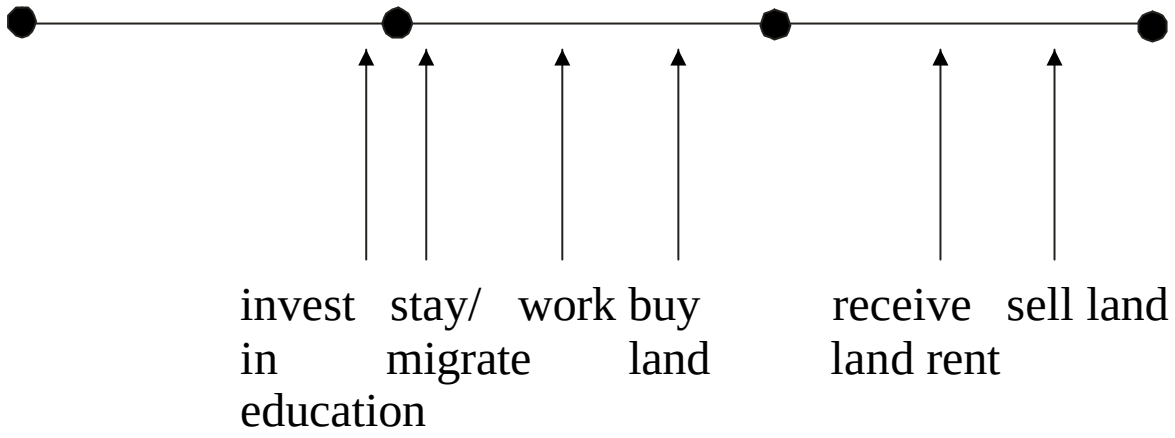

Figure 3. Timing with private education and mobile labor.

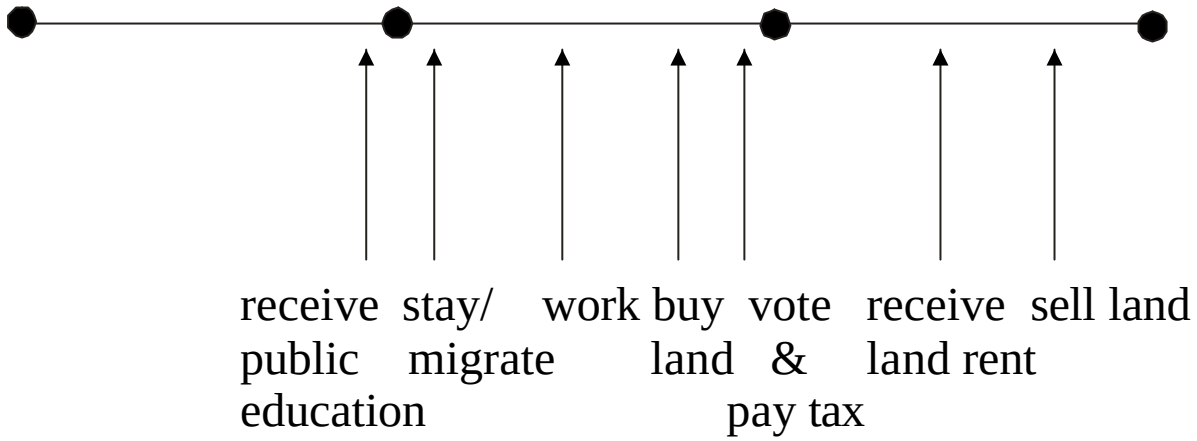

Figure 4. Timing with public education and mobile labor.