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Educational opportunity and income inequality

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Abstract

Affordable higher education is, and has been, a key element of social policy in the United States with broad bipartisan support. Financial aid has substantially increased the number of people who complete university—generally thought to be a good thing. We show, however, that making education more affordable can increase income inequality. The mechanism that drives our results is a combination of credit constraints and the 'signaling' role of education first explored by Spence [Spence, A. Michael, 1973. Job Market Signalling, Quarterly Journal of Economics, 87(3) Aug., 355–374]. When borrowing for education is difficult, lack of a college education could mean that one is *either* of low ability *or* of high ability but with low financial resources. When government programs make borrowing or lower tuition more affordable, high-ability persons become educated and leave the uneducated pool, driving down the wage for unskilled workers and raising the skill premium.

JEL classification: D82; I22; I28; J31
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[With the G.I. Bill,] for the first time, the link between income and educational opportunity was broken. —Diane Ravitch in The Troubled Crusade: American Education 1945–1980 (1983)

1. Introduction

Governments at both the national and the state level in the United States spend large sums of money to make education affordable for the average American. Although subsidized state universities date to the 19th century, a focus on making college affordable for all dates to the Second World War. Starting with the GI Bill in 1944, the federal government has provided an ever-expanding package of grants, subsidized loans, subsidized 'work-study' jobs and other financial devices to college-going Americans. The results speak for themselves: between 1947 and 1999, the percentage of people 25 years old and over who had completed 4 or more years of college increased from 5.4% to 23.6%. By 2001, direct appropriations and grants at the state and federal levels had grown to $86 billion a year.[1] Nevertheless, many policy makers still think that college tuition remains a substantial and possibly insurmountable financial burden for American families. Ten bills directly addressing financial assistance for postsecondary education were proposed in Congress during 2003.[2] Both main candidates in the 2004 U.S. presidential election advocate making college more affordable. Bush touts his plan for "Strengthening Access to Post-Secondary Education and Job Training".[3] The Kerry campaign website says, "...every young person who works hard and wants to go to college should be able to afford it".[4]

Why does everyone think that making higher education affordable is a worthy goal for public policy? Many argue that education has positive social externalities. But others make the case that broader access to education promotes equality. For example, Harvard University President Larry Summers said in a Wall Street Journal interview, "No doubt, without this progress in promoting access to higher education, inequality would be even higher".[5]

In this paper, however, we argue that making education more affordable can lead to higher income inequality. We look at a world in which education acts as a signal of ability and households are credit-constrained, and we show that improved educational opportunity can increase wage inequality. The mechanism that drives our results is the 'signaling' role of education first explored by Spence (1973). Following his model, we make education costly in terms of tuition and effort, and the effort required is greater for low-ability persons. When households face credit constraints, lack of education could mean one of two things: low ability; or high ability and low financial resources. In other words, in contrast to Spence's model where differences in educational attainment can arise

1 See Section 4 for details.
2 See http://www.senate.gov.
3 See http://www.georgebush.com/Education/Brief.aspx.
4 See http://www.johnkerry.com/education.
5 "Bush, Kerry Duel, Differ on College Costs", by David Wessel, *The Wall Street Journal*, July 29, 2004.

only as a consequence of heterogeneity in ability, differences in educational attainment in our model reflect either heterogeneity in ability *or* financial resources. The wage of uneducated workers reflects the mix of abilities: the smaller the proportion of high-ability persons in the uneducated pool, the lower the wage for unskilled labor. Thus, as we improve opportunities for higher education, either by providing direct grants for tuition or by reducing the interest rate that households pay to borrow for an education, more high-ability workers get an education and the quality of the unskilled pool drops, lowering the unskilled wage.

How important an effect is this? We ask the reader to consider the following question. Suppose you meet two people without any postsecondary education, one born in 1915 and the other born in 1975. Is your inference about their abilities relative to their cohorts the same? We argue that any inference about their lack of college education should be quite different. Very little information is conveyed about the ability of the individual who grew up in the earlier period with fewer opportunities, while a stigma is associated with a lack of education in more recent times.

In the paper, we formalize the above intuition in a simple model of wage determination. We first consider a static model and frame our results in the standard labor supply and labor demand paradigm. We show that the assumptions of a signaling role for education and credit constraints lead to an upward sloping demand curve for unskilled workers. Firms are willing to pay unskilled workers more when they are more likely to be of high ability. Thus, lowering tuition and the interest rate on borrowing leads to a reduction in the supply of unskilled workers, which in turn lowers the wage of unskilled workers.

We then consider a multi-generation framework, in which households consume and leave bequests for their children, who can use the bequests to pay for education. We show that a scenario may emerge in which, as more and more high-ability workers become educated, the wages of unskilled workers fall. We call this the "kick-down-the-ladder" scenario since falling wages make it progressively more difficult and eventually impossible for the remaining high-ability, low-wealth households to accumulate enough money to make the leap to education. The first generations of high-ability households that make the leap to skill kick down the ladder of opportunity for subsequent generations. We show that in some cases, though, intergenerational wealth transfers can overcome the problem of credit constraints and allow all high-ability persons to get an education. Of course, this comes at a cost of higher inequality.

We believe our paper is relevant from both positive and normative angles. First, our model shows that more equality in opportunities can lead to more inequality in outcomes, contrary to common wisdom. Second, the expansion of educational opportunity in the United States in the postwar era coincided with a significant expansion in the skill premium. Such an outcome is inconsistent with standard supply-and-demand analysis, in which the increase in supply of skilled labor should reduce the relative wage of skilled workers, but it is consistent with our model's conclusions.

Nevertheless, we do not view our results as a definitive explanation of the skill premium or anything even close to that but as a contribution to such an explanation. Moreover, in the model we take the extreme position that education plays only a signaling role, an assumption that was made purely for expositional ease. Adding a productivity-enhancing aspect to education would not change our basic results.[6]

The paper proceeds as follows. In the remainder of this section, we discuss the relevant literature. In Section 2, we discuss our static model. In Section 3, we extend the model to a multi-generation world. In Section 4 we look at empirical evidence. A brief conclusion follows in Section 5.

1.1. Related literature

Our work touches on three bodies of literature in economics. First, researchers starting with Spence (1973) have explored the role of signaling in labor markets. Since Spence's seminal article in 1973, the debate over the validity of education as a signal versus its value in building human capital has been heated. A review of the debate can be found in Fang (2000). Bedard (2001) argues for the significance of the role of signaling, examining the effect of increased access to universities on individuals' incentives to drop out of high school. She provides empirical evidence that signaling has a role in determining behavior. In the paper most similar to ours, Krugman (2000) argues that signaling could play a role in the expansion of wage inequality in the postwar era. In Krugman's model, households do not face credit constraints, and the increase in wage inequality comes from moving from one equilibrium with low inequality to another with high inequality. Our model does allow for multiple equilibria with high and low inequality, but multiple equilibria do not play a role in our analysis of the dynamics of the skill premium.

Researchers have explored many reasons why wage inequality has changed over time in the United States and in other countries. Most studies analyzing the college premium have focused on demand factors; technology-skill complementarities and international trade's effect on skill composition are the most prominent explanations. For surveys of the literature, see Acemoglu (2002), Levy and Murnane (1992), and Aghion et al. (1999). Katz and Murphy (1992) also point to the rate of change in the supply of college graduates as one explanation of the data. Theoretical studies have had difficulty in capturing two aspects of the increasing skill premium: the decline of unskilled wages over the past 25 years and an endogenous increase in education levels. Acemoglu (1999) and Caselli (1999) resolve the first issue since the capital/labor ratio for unskilled workers falls endogenously in their papers. Acemoglu (1998) addresses the second issue. Galor and Moav (2000) and Gould et al. (2001) are able to capture both aspects, with the first coming through a depreciation of skill due to technological progress.

Finally, our model builds on theoretical papers in which imperfections in the credit market determine income distribution dynamics (for example, Loury, 1981; Banerjee and Newman, 1993; and Aghion and Bolton, 1997). Our contribution is to use signaling as the basis for wage formation. Formally, our model draws from Galor and Zeira (1993). Fernandez and Rogerson (2001) also look at inequality in a model in which credit market imperfections affect educational attainment decisions, but with a different wage formation mechanism.

[6] We discuss the impact of productivity enhancing education in Section 3.4.

2. The static model

We first consider a static model of wage determination similar to that of Spence (1973). The individual decision problem is whether to get an education. Education is costly as worker i must pay a tuition of T dollars and also incur an effort cost k_i, which is inversely related to her ability. The payoff to education is that educated workers earn wage w^e, which typically exceeds the wage of uneducated workers w^n. Firms value ability but can only observe a worker's level of education. As in Spence, education does not enhance productivity and serves only as a signal of type. We add heterogeneity to the model by positing that workers receive bequests from their parents. For some workers, the bequest is sufficient to cover the cost of tuition, and these individuals can invest any surplus in a riskless bond which yields the "lending interest rate" r_L. For others, however, the bequest is insufficient to cover tuition; in this case, if they want an education, they need to borrow at the "borrowing interest rate" r_B, which is greater than r_L. As in Galor and Zeira (1993), we assume that the credit market is imperfect because of the possibility of default and monitoring costs spent by the lender to prevent that default.[7,8] This specification also admits simple transaction costs and is therefore quite general. The existence of a substantial wedge between the cost of borrowing and the return on lending is fundamental to our model, as it makes education too costly for some individuals who would otherwise benefit from the skill premium it offers.

Our central result is that the demand curve for unskilled labor is *upward* sloping. In a stable equilibrium, reductions in the supply of unskilled labor lead to a fall in the price of unskilled labor and therefore an increase in the skill premium. Thus, reductions in the borrowing interest rate and tuition, which decrease the supply of unskilled labor by making education attractive, lead to increases in the skill premium.

In the remainder of this section, we construct a formal version of the model described above. We then show that a stable equilibrium exists and perform some comparative statics. For now, we take the distribution of wealth as given. In Section 3, we consider an infinite-period version of the model in which the distribution of wealth evolves endogenously.

2.1. The model

We assume that there is a mass 1 of workers. A proportion π of them are high-ability workers, and a proportion $1-\pi$ are low-ability. High-ability workers produce q^H units of output when working, and low-abilities workers produce q^L, where $q^H>q^L$.

[7] Aghion and Bolton's (1997) model defaults risk explicitly as a hidden action problem and explain the development process through interest rate dynamics. We are more interested in the role of education in income dynamics and hence simplify the capital market interactions.

[8] Default risk is an important phenomenon in the market for education loans. Such loans are very rarely made without some form of government subsidy because of the risk. In 1990, U.S. expenditures on defaults amounted to about \$3 billion, which was approximately one-fourth of the loan volume.

In addition to differing in ability, workers differ in the indirect cost of getting an education k_i where $k_L > k_H$. Our notion of indirect cost captures the idea, from Spence (1973), that higher education is more challenging for low-ability students than for high-ability students. Spence measures the added effort required for low-ability students to complete college as an argument of the utility function. For practicality, we model it as a monetary cost (needing tutors, supplemental materials, or simply time costs). The results would be identical either way. Without loss of generality, we assume that $k_H = 0$.

Firms compete Bertrand-style for workers by making simultaneous offers. Firms can only observe a worker's education and set wages. We therefore assume that firms cannot observe abilities or bequests. Firms do know the proportion of high-ability workers in the population as well as the bequest distributions. In any equilibrium,

$$w^e = E(q|\text{education}) \tag{1}$$

$$w^n = E(q|\text{no education}). \tag{2}$$

Workers live for one period. At the beginning of the period, a worker of type i receives bequest b_i (drawn from a distribution of bequests for type i) and decides whether to get an education. If the worker decides not to get an education, then she receives income:

$$y_i^n = w^n + b_i(1 + r_L).$$

If she does decide to get an education, then she pays tuition T and cost k_i. Her income depends on whether her bequest exceeds the total cost of an education. If $b_i \geq T + k_i$, then the worker can pay for an education out of her bequest, invest the balance in bonds, and earn income:

$$y_i^e = w^e + (b_i - T - k_i)(1 + r_L).$$

If $b_i < T + k_i$, then the worker borrows to pay for an education and gets income:

$$y_i^e = w^e - (T + k_i - b_i)(1 + r_B).$$

A worker chooses to get an education if and only if $y_i^e > y_i^n$.

In order to study the role of financial market imperfections in an education signaling framework, we restrict attention to parameters that yield a separation of types in equilibrium. First, we assume that the cost of education for the low-ability workers is sufficiently high that they never get an education. Specifically, we assume that even with the highest possible skill premium ($q^H - q^L$), a worker of low ability will still prefer to invest her bequest in bonds:

$$\frac{q^H - q^L}{T + k_L} < 1 + r_L. \tag{3}$$

Second, we assume that getting an education will be attractive for at least the richest high-ability workers. If we define $\bar{q} \equiv \pi q^L + (1 - \pi) q^H$ as the average ability when both types are pooled together, our assumption implies that even with the lowest possible skill premium, a high-ability person with a bequest above her cost of education will find it profitable to invest in an education:

$$\frac{q^{\mathrm{H}}-\bar{q}}{T}>1+r_{\mathrm{L}}. \tag{4}$$

Eqs. (3) and (4) ensure that an equilibrium exists where at least some high-ability persons get educated and where no low-ability persons get educated and that there are no pooling equilibria where all members of both types take the same action (for appropriate off-the-equilibrium-path-beliefs).[9]

2.2. Supply and demand

We now characterize the labor market. Since no low-ability persons ever get an education, the wage of educated workers is fixed at $w^{\mathrm{e}}=q^{\mathrm{H}}$. Therefore, we focus on the market for unskilled labor.

We define the supply curve for unskilled labor as the probability that a high-ability worker is unskilled, or $P(n|H)$. From Eq. (4), we know that all high-ability workers with $b_i \geq T$ will get an education. What about high-ability workers with $b_i < T$? Such workers will get an education if:

$$w^{\mathrm{e}}-(T-b_i)(1+r_{\mathrm{B}})>w^{\mathrm{n}}+b_i(1+r_{\mathrm{L}}).$$

or alternatively if:

$$b_i>\frac{T(1+r_{\mathrm{B}})-(w^{\mathrm{e}}-w^{\mathrm{n}})}{r_{\mathrm{B}}-r_{\mathrm{L}}}\equiv b^*.$$

Thus, our supply curve is:

$$P(n|H)=P(b_i \leq b^*). \tag{5}$$

where $P(\cdot)$ represents the cumulative density function of the bequest distribution for high-ability workers.

[9] Formally, we define a signaling equilibrium as choices of education based on skill and bequest level ($\xi^*(q, b) \in \{e, n\}$), beliefs by firms about type given education ($\mu(H|\xi)$ for $\xi \in \{e, n\}$), and wages as defined above. We employ the solution concept of Perfect Bayesian equilibrium. Inequality (3) guarantees the existence of the separating equilibrium. Pooling in education is not possible, as Eq. (3) shows that low-ability persons would like to deviate. Pooling in no education can exist if high-ability persons do not want to deviate. Clearly there are off-equilibrium-path beliefs by firms that would keep high-ability persons from deviating (for example, if firms believe someone with an education is low-skill), but using the Intuitive Criterion of Cho and Kreps (1987), we can eliminate these beliefs as unreasonable. Since inequality (3) guarantees that low-ability persons would never choose to get an education, the beliefs of firms upon seeing education must be that the individual is of high ability. Lastly, inequality (4) ensures that a rich high-ability person finds it profitable to deviate from the pool and signal her ability through education.

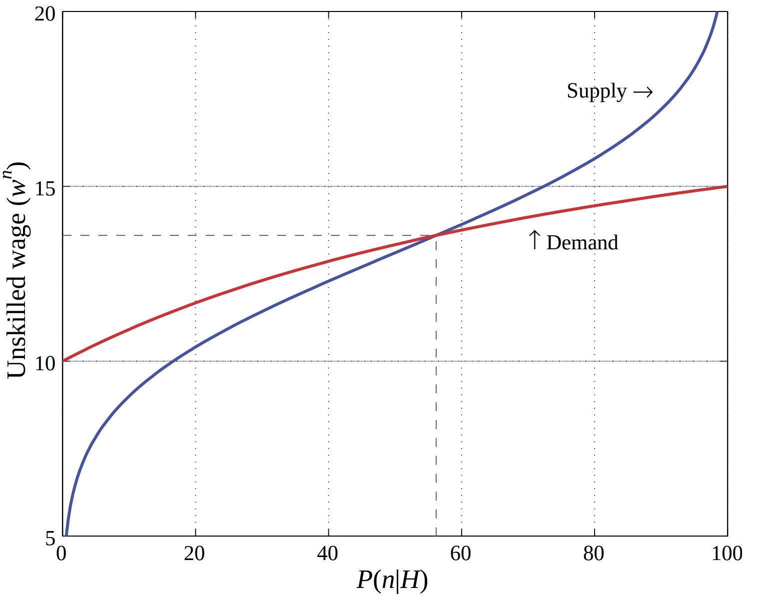

Fig. 1. Equilibrium in the market for unskilled labor.

Fig. 1 shows an example of a supply curve. For expositional simplicity, we assume that worker bequests are normally distributed. In that case, the supply function is a linear transformation of a normal random variable.[10]

How do the parameters of the model affect our supply curve? An increase in the unskilled wage raises the wealth cutoff b^* by reducing the payoff to education, which raises $P(n|H)$. Hence, the supply curve is upward sloping. An increase in tuition level T increases b^* by driving down the return to education. So, for any given unskilled wage, more workers choose not to get an education, shifting the supply curve to the right. An increase in the wedge $r_B - r_L$ (the difference between the borrowing rate of interest and the lending rate of interest) both shifts the supply curve to the right *and* reduces its slope. To see why, re-write b^* as

$$b^* = T - \frac{(w^e - w^n) - T(1 + r_L)}{r_B - r_L}. \tag{6}$$

From the equation above and Eq. (3), it is clear that for any given skill premium, an increase in the wedge leads to a higher b^* and thus a higher supply of unskilled labor. Furthermore, a bigger wedge raises the slope of the supply curve. Intuitively, an increase in the wedge means that workers are more sensitive to changes in the skill premium.

We define the demand curve as the firms' willingness to pay for a given mix of high and low-ability workers. Since firms compete for workers, their willingness to pay is

[10] To see the familiar normal cdf, you need to turn the graph on its side—remember that probability is on the x-axis, not the y-axis.

uniquely defined by the break-even point of offering a wage equal to expected productivity. Strictly defined, the curve we describe is not a demand curve since although it does describe a relationship between price and quantity from the demand side, expected productivity is not held fixed when quantity is varied. What we describe then is more a 'willingness to pay' curve; however, in order to fix ideas we will abuse the terminology and label it a demand curve.

To compute the demand curve, we use Eqs. (1) and (2) to determine the skill premium:

$$w^{\mathrm{e}} - w^{\mathrm{n}} = \left(q^{\mathrm{H}} - q^{\mathrm{L}}\right)\left(\frac{1-\pi}{1-\pi+\pi \cdot P(n|H)}\right).$$

To get demand we solve for $P(n|H)$:

$$P(n|H) = \frac{1-\pi}{\pi}\left(\frac{q^{\mathrm{H}} - q^{\mathrm{L}}}{w^{\mathrm{e}} - w^{\mathrm{n}}} - 1\right) \tag{7}$$

Fig. 1 shows an example of a demand curve for unskilled workers. As one can see from the figure and from Eq. (7), the demand curve for unskilled workers is upward sloping—the feature of our model that drives many of our findings. Intuitively, as fewer and fewer workers get an education, firms realize that the average uneducated worker is more and more likely to be of high ability. Thus, they are willing to pay more for unskilled workers.

2.3. Equilibrium

To solve for the equilibrium, we set supply equal to demand. An equilibrium occurs when the percentage of high-ability workers who decide not to get an education at an unskilled wage w^{n} is equal to the percentage of high-ability workers that a firm needs to be in the unskilled pool of workers in order to break even by offering wage w^{n}. Formally, define $f(\cdot)$:

$$f : \mathbb{R}^3 \rightarrow \mathbb{R} : f(w^{\mathrm{n}}; T, r_{\mathrm{B}}) = \frac{(1-\pi)q^{\mathrm{L}} + \pi q^{\mathrm{H}} \cdot P(b_i < b^*(w^{\mathrm{n}}; r_{\mathrm{B}}, T))}{1-\pi+\pi \cdot P(b_i < b^*(w^{\mathrm{n}}; r_{\mathrm{B}}, T))}.$$

For a given r_{B} and T, equilibrium occurs when $f(w^{\mathrm{n}})=w^{\mathrm{n}}$. We focus our attention on locally tatonnement stable equilibria. That is, we assume that prices evolve according to:

$$\partial w^{\mathrm{n}} / \partial t = f(w^{\mathrm{n}}) - w^{\mathrm{n}}.$$

An equilibrium is locally tatonnement stable (which we will refer to as stable) if there exists $\epsilon>0$ such that if we perturb the equilibrium price within an ϵ-neighborhood, the economy returns to the same equilibrium.

The condition of tatonnement stability is equivalent to the requirement that the slope of the supply curve must exceed the slope of the demand curve. Fig. 1 shows a tatonnement-stable equilibrium. We can now state our existence result.

Proposition 1. *If we assume that (1) $P(\cdot)$ is continuously differentiable and $\partial P/\partial b^* \neq 0$ for all $b^* \in \mathbb{R}$ and (2) $P(b_i < b^*(q^H - \bar{q})) > 0$, then there generically exists at least one stable equilibrium.*

Proof. See Appendix A. □

2.4. Comparative statics and multiple equilibria

In a stable equilibrium, anything that makes it easier or more attractive for people to become educated raises the skill premium. The intuition is simple. Lowering the borrowing rate or tuition shifts the supply curve for unskilled labor to the left. With a normal downward-sloping demand curve, such a shift leads to a *rise* in the wage since demand would exceed supply. Because of the upward-sloping demand curve, however, increasing the wage would only make matters worse in our model. Fewer unskilled workers means that a larger fraction of them are of low-ability so firms are willing to pay less to hire them. Hence, decreasing the wage restores equilibrium.

In our model, policies that equalize opportunities to get education–lower r_B or T–actually increase inequality. But what about policies that attempt to reduce inequality directly? Suppose, for example, we introduce a progressive income tax which equals τ for educated workers and, without loss of generality, equals zero for unskilled workers. Now,

$$b^* = T - \frac{(w^e - \tau - w^n) - T(1 + r_L)}{r_B - r_L}.$$

An increase in the tax τ raises b^*, which increases the supply of unskilled labor, raising the unskilled wage and lowering the *pretax* skill premium. Thus, the features of our model, credit constraints and signaling, accentuate the equalizing effects of a progressive income tax.

We summarize this logic in the following proposition:

Proposition 2. *In any stable equilibrium, a fall in either the borrowing rate or tuition increases the skill premium. Imposing a progressive tax rate τ lowers the skill premium.*

Multiple equilibria are endemic to our model. Generically, there are an odd number N of equilibria, and $(N-1)/2+1$ of them are stable. If we assume that the distribution of bequests is normal, then we can have as many as three equilibria, two of which are stable. Fig. 2 shows an example. Multiple equilibria emerge when the concentration of workers strengthens to such a point that the slope of the supply curve drops below that of the demand curve. Starting at a stable equilibrium, an increase in the unskilled wage leads both supply and demand to increase, which initially results in excess demand. But when we hit the high-concentration part of the distribution, supply increases more quickly than demand, and we get to an unstable equilibrium. Overall, the intuition for multiple equilibria is straightforward. Since increases in the unskilled wage lead to increases in both supply and demand, we can get an equilibrium in which the skill premium is low and few get an education and an equilibrium in which the skill premium is high and almost everyone gets an education.

To see why stability is important, consider Fig. 2, which shows a model in which there are both stable and unstable equilibria. A reduction in tuition shifts the whole supply curve inward. In the two stable equilibria, such a shift leads to a reduction in the number of unskilled workers and a reduction in their wage. In the unstable equilibrium, an upward

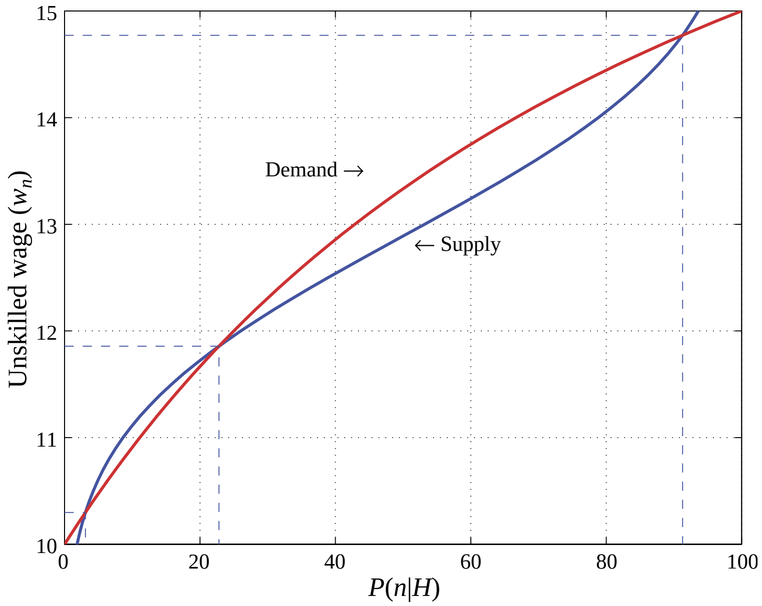

Fig. 2. An economy with three equilibria in the market for unskilled labor.

shift in supply leads to an increase in both the wage and the number of unskilled workers. Hence, in an unstable equilibrium, the comparative statics that we discuss in the proposition would generate the opposite results.

3. The dynamic model

In Section 2, we showed how the distribution of wealth affects both the equilibrium level of educational attainment and the equilibrium skill premium. But in a multi-generation world, both the level of educational attainment and the wage affect the wealth distribution of future generations, thus having a feedback effect on the steady-state levels of educational attainment and the skill premium. For example, if the wage for unskilled labor is high, an individual who fails to get an education in the present generation may still accumulate enough savings to allow the next generation to get an education, thus driving up the skill premium. Alternatively, if the borrowing interest rate is sufficiently high, an individual may be able to afford an education this generation, but that investment may deplete her savings so much that the next generation may forgo an education, driving down the skill premium. In this section, we generalize our model and characterize the evolution of the equilibrium skill premium and the level of educational attainment over generations. We consider dynasties composed of individuals similar to those in the previous section with the exception that they derive utility not just from consumption but also from bequests to their children. To simplify the exposition, we will refer to the bequest received by the time t generation as the *wealth* of a dynasty at time t.

There are two possible outcomes of the dynamics in our model. In Case 1, the population separates into two groups; all high-ability dynasties with initial wealth above a certain level get an education and all those with wealth below that level end up unskilled, regardless of whether they initially could afford an education. In this case, the skill premium falls over time. In Case 2, all high-ability uneducated dynasties initially experience intergenerational wealth growth, and some make the leap to skill. If the initial number of uneducated, high-ability workers is relatively small, all high-ability dynasties end up skilled in the steady state, even those with low initial levels of wealth. If the initial number of uneducated, high-ability workers is high, then high-ability workers with sufficiently low initial wealth end up unskilled in the steady state. The problem is that increasing skill levels lead to falls in the unskilled wage, making it increasingly difficult and eventually impossible for high-ability, low-wealth workers to accumulate savings for an education. We call this a "kick-down-the-ladder" scenario—dynasties that make the leap to skill make it increasingly difficult for successor unskilled dynasties to follow in their footsteps.

3.1. Evolution of the wealth distribution

Formally, we follow Galor and Zeira (1993) and characterize preferences over current consumption and bequests to the next generation with a Cobb-Douglas utility function:

$$u = \alpha \ln c + (1 - \alpha) \ln b,$$

where c is consumption, b is bequest size, and α is a taste parameter between 0 and 1.[11] Cobb-Douglas utility implies that both consumption and bequests are proportional to total lifetime income (that is, $c=\alpha y$ and $b=(1-\alpha)y$), and therefore individuals make their education decision in exactly the same way that they do in the static model in Section 2.[12] We assume that each individual lives for one period and has one child, who lives in the following period, to whom he or she bequeaths wealth. We call a chain of parents and children a dynasty, and for now we assume that all members of a dynasty have the same ability. (We relax this assumption in Section 3.3.) Consequently, we can analyze the dynamic model as a series of static models linked by the distribution of bequests. The initial wealth distribution for high-ability persons is given by a cdf $P_0(b)$, and the (endogenous) distribution for generation t is given by $P_{t-1}(b)$. Lastly, we retain all the assumptions of the previous section. In particular, we still assume that low-ability persons still never want to get an education.[13] Thus, education is still a perfect signal of ability, and $w_t^e = q^H$ for all t. However, both the

[11] Aghion and Bolton (1997) assume a similar utility function. They point to evidence that parents gain utility from bequests independent of the actual utility gained by children (see Andreoni, 1989).

[12] Formally, maximizing utility subject to a budget constraint $c+b=y$, where y is equal to lifetime income, yields $c=\alpha y$ and $b=(1-\alpha)y$. The indirect utility of the worker therefore equals $\ln y+\alpha\ln\alpha+(1-\alpha)\ln(1-\alpha)$. Since the first term is increasing in y and the second term is constant, lifetime utility is proportional to y, regardless of α.

[13] We discuss this assumption in Section 3.3.

wage of the uneducated worker w_t^{n} and the wealth cutoff for education b_t^* evolve over time.

The dynamics take place through the bequest function $\mathcal{B}_t(b_{t-1})$, which relates bequests received (which we call wealth) to bequests given (which we call bequests). Since we assume that low-ability individuals never want to get an education, we again focus on high-ability individuals. If an individual's wealth is below b_{t-1}^*, then he opts not to get an education and leaves a bequest of:

$$\mathcal{B}_t(b_{t-1}) = (1-\alpha)\left(w_t^{\mathrm{n}} + b_{t-1}(1+r_{\mathrm{L}})\right).$$

If the individual's wealth is between b_t^* and T, then he borrows to finance an education and bequests:

$$\mathcal{B}_t(b_{t-1}) = (1-\alpha)(w^{\mathrm{e}} - (T - b_{t-1})(1+r_{\mathrm{B}})).$$

Finally, if an individual's wealth exceeds T, then he pays for education out of his savings and bequests:

$$\mathcal{B}_t(b_{t-1}) = (1-\alpha)(w^{\mathrm{e}} + (b_{t-1} - T)(1+r_{\mathrm{L}})).$$

Thus, the bequest received by the next generation, depicted by the solid line in Fig. 3, is an upward-sloping function of current wealth with kinks at b_{t-1}^* and T. The slope of the bequest function depends on whether the individual is borrowing (that is, if $b_{t-1}^* < b_i < T$), in which case it equals $(1-\alpha)(1+r_{\mathrm{B}})$. If not, it equals $(1-\alpha)(1+r_{\mathrm{L}})$.

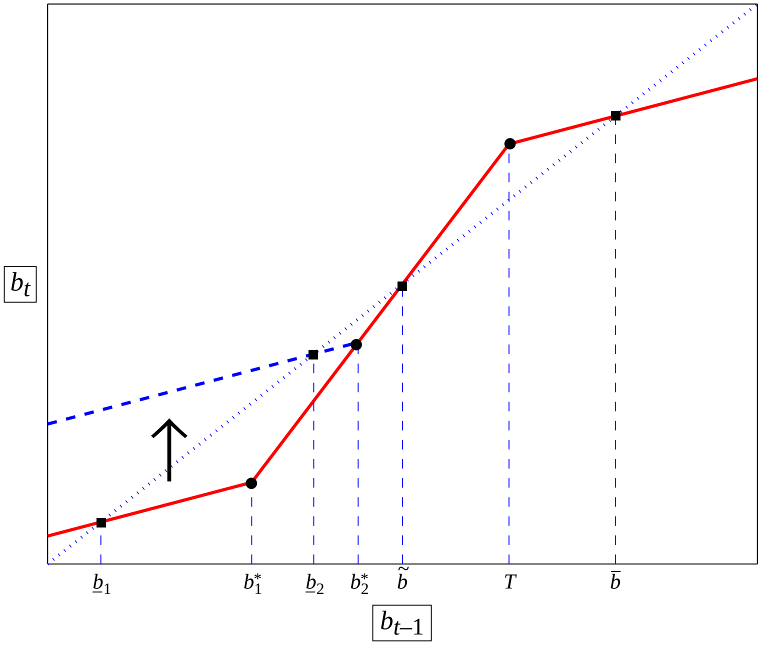

Fig. 3. Effect of an increase in w_t^{n} on the dynamics of bequests when $b^* < \tilde{b}$.

To ensure stable dynamics, we assume two conditions. First, we need a low interest rate for lenders. Formally, we require that:

$$(1-\alpha)(1+r_{\mathrm{L}})<1. \tag{8}$$

To see why, note that if Eq. (8) fails to hold, then a dollar increase or decrease in b_{t-1} leads to more than a dollar increase or decrease in b_t. So, if b_{t-1} is higher than b_t, bequests will explode upwards. Graphically, Eq. (8) means that when a dynasty is saving, the slope of $\mathcal{B}_t(b_{t-1})$ is less than 45°. Second, we require that if an individual pays for education out of his wealth, his bequest must exceed the cost of the education. Essentially, if the individual can afford to get an education without borrowing, then his immediate descendent can too. If this were not the case, low levels of altruism by the rich would lead to an uneducated population. Formally,

$$(1-\alpha)q^{\mathrm{H}}>T. \tag{9}$$

Eq. (9) implies that the function $\mathcal{B}_t(b_{t-1})$ exceeds the 45° line when b_{t-1} equals T (as depicted in Fig. 3). It is easy to see that if Eq. (9) does not hold, all dynasties forego education in the long run.

Next, in order to give capital market imperfection bite, we impose the condition that the wedge between borrowing and lending is sufficiently large, or:

$$(1-\alpha)(1+r_{\mathrm{B}})>1. \tag{10}$$

Eq. (10) ensures that the cost of borrowing is sufficiently large that all high-ability individuals will not end up trivially in getting an education (as they would in perfect capital markets where r_{B}=r_{L}).

The dynamic evolution of the wealth distribution depends on the initial wealth distribution and the parameters. We can separate the evolution into two cases, depending on whether $\mathcal{B}_1\left(b_0^*\right)$ is above or below the 45° line (equivalently, greater than or less than b_0^*). Intuitively, it depends on whether the dynasty in period 0 that is indifferent between becoming educated and not becoming educated gives enough money to its immediate descendent so that its members, too, can get educated. If it does not (and $\mathcal{B}_1\left(b_0^*\right)$ is below the 45° line), the economy follows a path of decreasing education and thus decreasing wage premia (Case 1). If it does (and $\mathcal{B}_1\left(b_0^*\right)$ is above the 45° line), the economy follows a path of increasing education and thus increasing wage premia (Case 2).

In Case 1, dynasties converge to two categories: unskilled and low wealth or skilled and high wealth. Fig. 3 shows an example of Case 1 for high-ability individuals. The three intersection points of $\mathcal{B}_t(b_{t-1}^*)$ with the 45° line define the dynamics, with each point corresponding to a stable level of bequests (that is, wealth equals bequests) for each of three different groups:

$$\underline{b}_1=\frac{(1-\alpha)w_1^{\mathrm{n}}}{1-(1+r_{\mathrm{L}})(1-\alpha)}$$

for high-ability unskilled workers;

$$\tilde{b}=\frac{(1-\alpha)(q^{\mathrm{H}}-T(1+r_{\mathrm{B}}))}{1-(1+r_{\mathrm{B}})(1-\alpha)}$$

for high-ability skilled workers who must borrow to finance education; and

$$\bar{b} = \frac{(1-\alpha)(q^{\mathrm{H}} - T(1+r_{\mathrm{L}}))}{1-(1+r_{\mathrm{L}})(1-\alpha)}$$

for high-ability skilled workers who can finance education out of saving. In each case, the stable point depends on the relevant wage (skilled or unskilled), the relevant interest rate (borrowing or lending), and the preference parameter α. Since the interest rates and the skilled wage are time-independent, $\tilde{b}$ and $\bar{b}$ are as well—hence the lack of time subscripts. But since the unskilled wage can evolve over time, $\underline{b}_t$ can as well.

The point $\tilde{b}$ divides dynasties. If bequests exceed $\tilde{b}$ for a given dynasty now, then eventually that dynasty will converge to wealth level $\bar{b}$, earning the skilled wage $w^{\mathrm{e}}=q^{\mathrm{H}}$. If wealth falls short of $\tilde{b}$ for a given dynasty, then that dynasty's wealth converges to $\underline{b}_t$, earning the unskilled wage w_t^{n}. Falling wealth implies falling levels of education, which implies higher wages for unskilled workers and thus a higher cutoff for education (b_t^* increases). Thus, the peculiar feature of our model–that increased supply of unskilled workers raises their wage–accelerates the dynamics. The skill premium converges to:

$$w^{\mathrm{e}} - w_{\infty}^{\mathrm{n}} = \left(q^{\mathrm{H}} - q^{\mathrm{L}}\right)\left(\frac{\pi_{\mathrm{L}}}{\pi_{\mathrm{L}} + \pi_{\mathrm{H}} \cdot P_0\left(b_i < \tilde{b}\right)}\right). \tag{11}$$

If there are enough initially low-wealth dynasties below $\tilde{b}$, the point $\underline{b}_t$ converges to $\tilde{b}$ in the steady state; that is, all low-wealth dynasties end up with wealth $\tilde{b}$. If there are not enough low-wealth dynasties, the dynamics stop at a point $\underline{b}_{\infty} < \tilde{b}$. Either way, Eq. (11) describes the skill premium.

The solid line in Fig. 4 shows the initial situation for high-ability persons in Case 2. Here, wealth levels rise for all dynasties with wealth below $\bar{b}$ regardless of whether they are skilled or not. But at some point, wealth levels of the unskilled start to exceed the education threshold b_t^*, and the number of skilled workers increases, driving the skill premium up and the threshold b_t^* down. If there are only a small number of dynasties with low wealth initially, all get an education before b_t^* reaches the 45° line. In that case, we get complete separation of types, and $w^{\mathrm{e}} - w_{\infty}^{\mathrm{n}} = q^{\mathrm{H}} - q^{\mathrm{L}}$.

If the number of dynasties with initial low wealth is sufficiently high, however, then eventually b_t^* falls below $\tilde{b}$, and $\mathcal{B}_t\left(b_t^*\right)$ drops below the 45° line. Now, of course, we are in Case 1 again. Households unlucky enough to have wealth below $\tilde{b}$ at the moment when b_t^* falls below it now switch directions and watch their wealth converge down to $\underline{b}_t$. The newly educated dynasties have kicked the ladder of educational opportunity down by making it too expensive to get an education. The skill premium, which was increasing while b_t^* was greater than $\tilde{b}$, converges to:

$$w^{\mathrm{e}} - w_{\infty}^{\mathrm{n}} = \left(q^{\mathrm{H}} - q^{\mathrm{L}}\right)\left(\frac{\pi_{\mathrm{L}}}{\pi_{\mathrm{L}} + \pi_{\mathrm{H}} \cdot P_{\infty}\left(b_i < \tilde{b}\right)}\right).$$

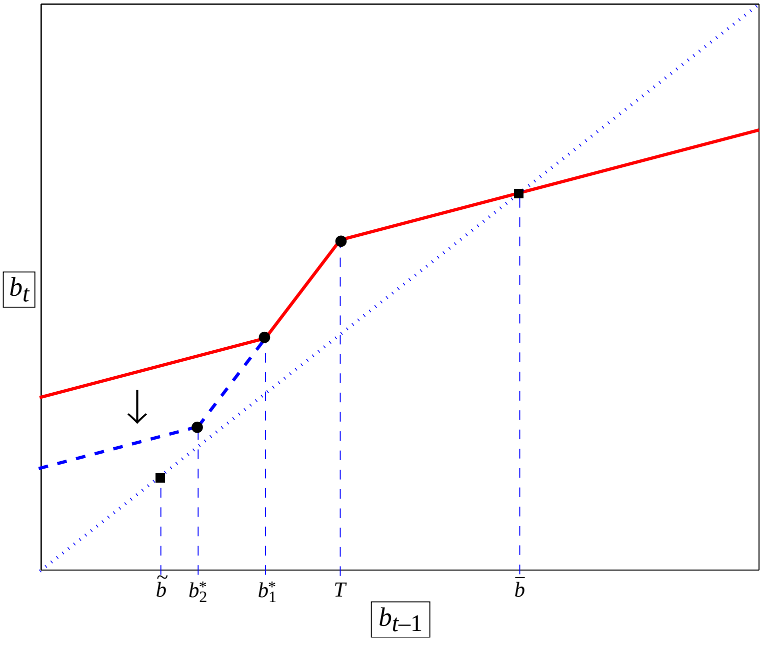

Fig. 4. Effect of a fall in w_t^n on the dynamics of bequests when $b^* > \tilde{b}$.

The dynamics for Cases 1 and 2 can be summarized in terms of supply and demand, further linking the analysis of this section to that of the static model. Within one period, Eqs. (5) (supply) and (7) (demand) determine the skill premium. For a given skill premium, the bequest function $\mathcal{B}_t(b_{t-1})$ describes how the distribution of dynasties changes in the next period. Given that distribution, the next period skill premium is determined. This continues until the steady state is reached. Changes in the distribution of bequests affect only the supply curve. Hence, the dynamics are essentially due to movements of the supply curve over time.

In Case 1, dynasties with wealth below $\tilde{b}$ leave lower bequests for their children. Those dynasties just above $\tilde{b}$ leave higher bequests for their children. Hence, the supply curve for unskilled individuals rotates around the point $P_0(b_i < \tilde{b})$, with the top part shifting inward and the bottom part shifting outward. The bottom part is the relevant part, and the outward shift increases the uneducated wage in the following period. This rotation continues, driving down the skill premium until the steady state is reached. In Case 2, all dynasties with wealth below $\bar{b}$ leave higher bequests for their children. This decreases the supply of uneducated individuals for every possible uneducated wage–shifting the supply curve inward–and decreases the uneducated wage. These same forces keep pushing the supply curve inward and the skill premium upward until the steady state is reached. Note that we end up with opposite dynamics and conclusions to Galor and Zeira (1993). The reason for this contrast is simple; in Galor and Zeira, the result is based on a human capital argument and hence on a traditional downward-sloping demand function, while ours depends on signaling and an upward-sloping demand function.

3.2. Determinants of the steady state

In this section, we address some natural questions about the dynamics. First, given some initial conditions, will the skill premium grow or shrink over time? Second, if the skill premium grows, will it eventually converge to a complete separation of types? Or will it stop at some intermediate point? Similarly, if the skill premium shrinks, will we get complete pooling?

In response to the first question, a smaller initial skill premium or a larger q^{L} makes it more likely that wage inequality will grow over time (that Case 2 occurs), holding fixed all other parameters of the economy. The intuition for the effect of the initial skill premium on the dynamics is straightforward. Recall from the previous section that Case 2, in which the skill premium rises over time, occurs when $\mathcal{B}_1\left(b_0^*\right)$ is above b_0^*, or equivalently, b_0^* exceeds $\tilde{b}$. From Eq. (6) we know that:

$$b_0^* = T - \frac{\left(w_0^{\mathrm{e}} - w_0^{\mathrm{n}}\right) - T(1 + r_{\mathrm{L}})}{r_{\mathrm{B}} - r_{\mathrm{L}}},$$

and we can re-write $\tilde{b}$ as:

$$\tilde{b} = T - \frac{(1-\alpha)q^{\mathrm{H}} - T}{(1-\alpha)(1 + r_{\mathrm{B}}) - 1}.$$

It is easy to see that if we hold fixed (r_{B}, r_{L}, T, q^{H}, q^{L} and α), the skill premium has no effect on $\tilde{b}$ but is inversely related to b_0^*. Thus, a lower initial skill premium makes it more likely that b_0^* exceeds $\tilde{b}$. A lower initial skill premium means that there are initially enough high-ability dynasties in the uneducated pool to make the uneducated wage high and the jump to education possible.

Next, using the equations for b_0^* and $\tilde{b}$, the implicit function theorem (w_0^{n} is a function of b_0^*), and the assumption that an equilibrium is stable, and holding fixed (r_{B}, r_{L}, T, and α), we can show that a larger q^{L} makes rising wage inequality more likely. A larger q^{L} makes b_0^* larger (which makes the wage differential smaller, meaning it is not as difficult to get an education), and does not affect $\tilde{b}$.

We now address the destination of the dynamics. For the decreasing skill premium case (Case 1), incomplete separation of types always results. In Section 2, we assumed that there was at least one household with wealth above T. According to the dynamics, such a household will always get an education, regardless of what happens to the skill premium. And as the skill premium falls, the number of unskilled workers rises, so the steady state always involves some unskilled and some skilled high-ability workers.

In the increasing skill premium case (Case 2), complete separation of types can arise. The basic question is whether all the high-ability dynasties can make the jump to education before the "ladder" of opportunity disappears. This depends on a minimum level of b^*, which occurs when there is complete separation of types and the skill premium is maximized. Define:

$$\min(b^*) = T - \frac{(q^{\mathrm{H}} - q^{\mathrm{L}}) - T(1 + r_{\mathrm{L}})}{r_{\mathrm{B}} - r_{\mathrm{L}}}.$$

Note that b_0^* must initially exceed min (b^*). Over time, more and more dynasties become educated and push b_t^* down. If min $(b^*)>\tilde{b}$, then all high-ability dynasties eventually get educated, and we get complete separation in the steady state. It is easy to see that if min $(b^*)\leq\tilde{b}$, incomplete separation of types can occur.

A reduction in the cost of education (lowering r_{B} or T) or skill-unbiased technological change (an increase in q^{H}, holding $q^{\mathrm{H}}-q^{\mathrm{L}}$ fixed) makes complete separation more likely, that is, it increases min (b^*) relative to $\tilde{b}$. Intuitively, lower costs of education or higher q^{H} means that educated dynasties bequest more for a given level of wealth, making it easier to sustain the choice of education.

Lastly, our model implies that the type of financial aid given, low interest rate loans or tuition subsidies, could be important. As we have noted, a large reduction in r_{B} would bring us close to the perfect capital markets case, and hence all high-ability dynasties would become educated. A large decrease in tuition costs would have the same effect, but may have an important side effect. Large decreases in tuition could change the equilibrium from separating to one where low-skill persons pursue an education. This can be seen from Eq. (3). It is also clear from Eq. (3) that lowering the interest rate on borrowing would have no such effect.

3.3. Robustness

In this section, we consider two extensions of the model. First, we discuss what happens when we relax the assumption that there are only two types and that only one type ever gets an education. Second, we consider what happens when dynasties can randomly mutate from one type of ability to another.

A natural question is whether our model is robust with respect to pooling of types and to multiple types. The answer is that it depends, and we illustrate this through two examples. First, suppose that Eq. (3) did not hold and that low-ability persons could get an education. If we assume that high-ability persons always get an education, then it is clear that the static model yields results that are opposite to ours. If we assume that some high-ability persons may not become educated, then our results may or may not hold depending on the wealth distribution of the high- and low-ability persons. Second, suppose that there are multiple types. If we make the assumption that only the highest-ability persons can get higher education, the results are the same as with our model. If not, then the solution will be dependent on the wealth distribution, as we described in the previous example.

Next, we examine the case where the model is the same, but a child may not have the same ability as his or her parent. This case involves a combination of the deterministic convergence presented in the previous section and a stochastic process followed by individuals' abilities. We define the transition from generation to generation by the probability λ^{H} (λ^{L}), which represents the proportion of high- (low-) ability individuals who get a high- (low-) ability heir. Bequest dynamics are identical to those in the preceding section as long as subsequent generations remain in the same type category. These dynamics are altered when a mutation takes place, in which case the convergence process resumes at the same income level, but following the law of motion of the new type.

In this case, there are three possible outcomes, which we summarize in the following proposition. A mathematical discussion of the dynamics is included in the Appendix A.

Proposition 3. *Allowing for mutations ($\lambda^H \neq 1$ and $\lambda^L \neq 1$) in the dynamic economy described in Section 3.1 yields three possible outcomes:*

- **(i)** *Pooling steady state: all individuals are uneducated, with wealth $\leq \tilde{b}$, and wage $w^n = \bar{q}$.*
- **(ii)** *Complete separation: all high-ability persons are educated, all low-ability persons uneducated, $w^n = q^L$, but wealth does not converge.*
- **(iii)** *No convergence in education or wealth.*

The pooling steady state has convergence in terms of wealth. If all individuals get pushed down the wealth distribution, there is no way to return. Both types have the same wealth ($\underline{b}_\infty \leq \tilde{b}$), bequeath that same wealth, and neither gets an education. On the other hand, if as in the deterministic model min $(b^*) > \tilde{b}$, then at some point in finite time all types must have wealth above b^*. When b_0^* starts out larger than $\tilde{b}$, both low-ability persons and high-ability persons with wealth below b^* bequest more than they receive. If min $(b^*) > \tilde{b}$, then, when the wealth of low-ability persons surpasses b^*, they continue to give more than they receive (for low-ability persons with wealth in $(b^*, \underline{b}_t)$). So high-ability persons who remain high-ability persons become educated dynasties, and low-ability persons who switch to high-ability persons become educated dynasties. Although the high-ability persons move toward $\bar{b}$ and low-ability persons move toward $\underline{b}_\infty$, wealth does not converge because of transitioning between types. Lastly, convergence depends very much on the original distribution of bequests, although it is difficult to provide general results about the nature of this dependence.

While the pooling steady state is quite different from the results with no mutations, the complete separation result is similar. The complete separation result must have increasing wage inequality over time on average. Whether the amount of education increases depends on transition probabilities. In the Appendix A, we analytically examine the case of mutations for certain parameters.

3.4. Welfare analysis

How does access to education affect welfare in our model? At first glance, our model may point to access being welfare reducing. First, we assume that education has no effect on worker productivity, improving access to education has no effect on the production of the aggregate economy and on growth. Second, education generates dead-weight losses from both the costly signaling of high-ability types (in the form of tuition and indirect costs) and the monitoring costs on loans. Finally, and more interestingly, improving access to education redistributes income towards high-ability workers, which could be undesirable depending on what type of social welfare measure we consider.

Since Spence's seminal article in 1973, the debate over the validity of education as a signal versus its value in building human capital has been heated. It is therefore important to see how productive education can change the results of our dynamic model. Suppose that the augmentation in productivity makes individual i's output ρq^i, $\rho > 1$. Furthermore, assume that the conditions for a separating equilibrium still hold. Intuitively enough, *none of the qualitative results change, but the welfare analysis may change substantially*. If the productivity enhancement outweighs the cost of education (that is, $(\rho - 1)q^i - T - k^i - I > 0$, where I is the loan monitoring cost), the steady state of keeping highly-skilled individuals from an education may be viewed as a very negative result. Depending on the parameters, the steady state may guarantee that a sizable number of individuals will eventually choose not to purchase an education, stifling growth. Any policy to counteract this necessitates some type of permanent intervention. This lies in contrast with temporary pro-growth policies in other papers (Banerjee and Newman, 1993 and Piketty, 1997; for a review of the literature see Aghion et al., 1999).

Topel (1997) discusses the implications of wage inequality in a policy context. Using the argument that demand has substantially outpaced supply, he recommends a policy of extensive investment in education to soak up excess demand. In the context of our model, which is outside of the standard supply and demand framework, such a policy would only increase inequality. While signaling is only one component of wage inequality, its effects certainly merit further investigation before such policies are fully supported.

4. Some evidence on financial aid and wage inequality

Our model predicts that in the presence of credit constraints, expanded financial assistance for education would result in increased wage inequality. In this section, we review evidence concerning three fundamental aspects of our model. We first offer background into financial aid for higher education in the United States and discuss the effectiveness of credit constraints. Next, we discuss the implications of our model for wage inequality and whether it lines up with the evidence in the United States and abroad. Finally, we discuss possible empirical implications our paper may have for the intergenerational mobility literature.

4.1. Federal subsidies for higher education

The key event in the history of federal policy toward education finance in the United States was the Serviceman's Readjustment Act of 1944 (more commonly known as the G.I. Bill of Rights), which provided World War II veterans with a wide array of benefits, including (for an unmarried veteran) a \$65 per month stipend and paid tuition up to \$500. Behrman et al. (1989, p. 400) emphasize the substantialness of these benefits: "annual U.S. per capita disposable income in 1946 was \$1,124, and the University of Pennsylvania's undergraduate tuition plus general fee, which is comparable to Harvard's, was \$495". Over 2.2 million veterans attended university using these benefits, peaking at 49.2% of enrolled students and 69.3% of enrolled males.[14] Estimates made at the time indicate that approximately 20% of the enrolled veterans would never have gone to college without the subsidies. Gutek (1986, p. 282) states, "Higher educational opportunities were made

[14] See Olson (1974) for detailed data.

available to a larger and more varied socioeconomic group than ever before. . .the idea that higher education was the privilege of a well-born elite was finally shattered". Subsequent G.I. bills for Korean and Vietnam War veterans proved less substantial.

In 1958, government aid was extended to non-veterans. Under the auspices of the National Defense Education Act, the federal government provided colleges with funds to lend at low interest rates to students; these loans were called Perkins loans. Perkins loans and similar subsequent programs required no collateral or credit history but had fixed borrowing limits and were typically based on demonstrated financial need.[15] The Higher Education Act of 1965 created a grant program and an additional loan program, the Guaranteed Student Loan or GSL Program. GSLs were handled by banks and savings and loan institutions and received subsidies in addition to a federal government guarantee of repayment. Later subsumed under the title of Federal Family Education Loans (FFEL), these loans quickly eclipsed the Perkins loans in terms of volume. In 1976, the Pell grant, a need-based grant, began, and the other programs were strengthened. There were no major changes in these programs until the mid 1990s, when the federal government began making direct student loans.[16]

Government financial assistance for higher education remains enormous. According to Kane (2003), direct appropriations and grants at the state and federal levels totaled \$86 billion in 2001. In addition, the federal government guaranteed \$37 billion in loans. In Fig. 5, we summarize the changes in borrowing. As one can see from the chart, the loan volume of FFEL loans increased from nothing in 1965 to over one quarter of 1% of GDP (over \$20 billion) in the mid 1990s. This offers a strong sense that the loans were less costly than outside opportunities. Over that same time frame, college entrance rates for recent high school graduates increased from 45% (1959) to 58.9% (1988).[17]

In Fig. 6, we depict the trade-off between borrowing and saving. The interest rate depicted as the borrowing rate is that of the Stafford loan, computed for each year X as the rate a person who took out a loan 4 years previously would have to pay in year X, that is, the rate that influences their decision.[18] The rate of interest on saving is shown as the return on a 6-month CD. For the most part, the wedge between borrowing and lending is apparent. The wedge between the return on a 6-month CD and commercial loans is substantially higher, indicating a high degree of subsidization by the government. The rigid low rates on Stafford loans actually brought them substantially below the saving rate from 1979 to 1984. Around this time the government's expenditures ballooned, as can be seen from the sharp increase in loan volume in Fig. 5.[19] The loan volume also increased

[15] Borrowing limits do not qualitatively affect our theoretical results, but should shift $\tilde{b}$ downward.

[16] An excellent summary of legislative activity and the history of student loans can be found in Mumper (1996).

[17] These data were culled from the organization Postsecondary Education Opportunity (http://www.postsecondary.org).

[18] Note that individuals who take out Stafford Loans do not have to pay interest while in school. The Stafford Loans (called Guaranteed Student Loans prior to 1981) make up the largest part of FFEL loans. These loans had fixed rates until 1993, when they became a function of the 91-day Treasury Bill. We thank Brian Smith of the Department of Education for his help in obtaining the data on Stafford Loans.

[19] We also note that college tuition, in real terms, was very stable in the 1970s and did not begin growing substantially until 1982. (These data can be found in College Board, 1999b.)

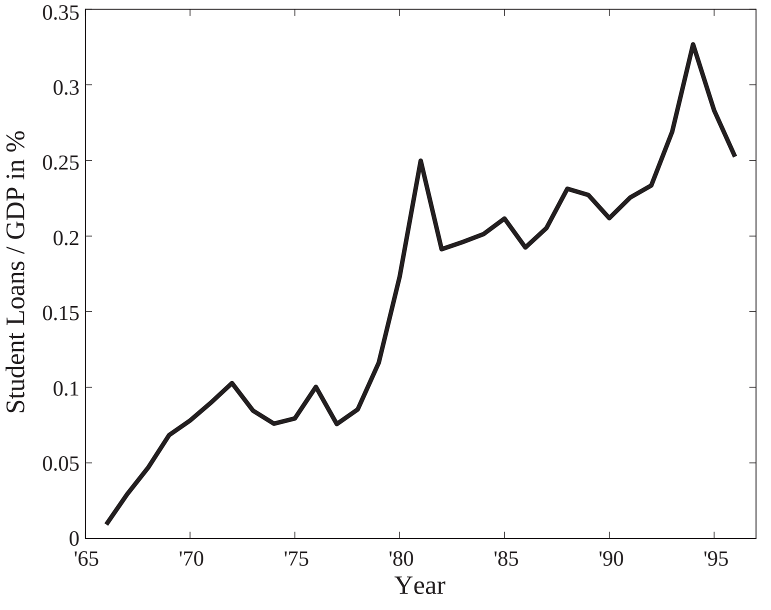

Fig. 5. Federal Family Education Loan volume as a percentage of GDP. Source: U.S. Department of Education and Council of Economic Advisors.

substantially in the 1990s, despite a relatively stable interest rate differential. This was motivated in part by increased loan limits, the introduction of unsubsidized loans, and favorable changes in qualification standards.

The existence of a wedge between rates for borrowing and rates for saving makes a great deal of sense when one observes the massive amount of organization in place to prevent defaults. Many state guarantee agencies and secondary market loan associations exist solely to recover loans.[20] Nevertheless, the prevalence of default is quite significant—in 1990 federal expenditures due to defaults amounted to approximately $3 billion, representing about one-half of total federal expenditures on loans and one-quarter of the loan volume in that year.[21]

Although suggestive, current evidence is inconclusive on the effect of credit constraints on educational attainment. The main fact on which researchers seem to agree is that cost represents a substantial deterrent to college attendance. The general consensus, as discussed in Kane (2003), is that a $1000 increase in college costs leads to a 4 percentage point fall in the rate of college attendance.[22] Cameron and Taber (2004) and others argue that more direct approaches show that borrowing constraints do not affect the education

[20] These are organizations which specialize in student loans and purchase them from primary lenders, that is, banks and savings and loan institutions. The largest of these is the Student Loan Marketing Association (better known as Sallie Mae).

[21] These numbers are drawn from Mumper (1996) and the College Board (1999a).

[22] That, in and of itself, is not evidence of credit constraints. As Dynarski (2003) says, "Since grant aid reduces the cost of schooling and thereby increases its optimal level, a behavioral response does not, per se, indicate the presence of capital constraints".

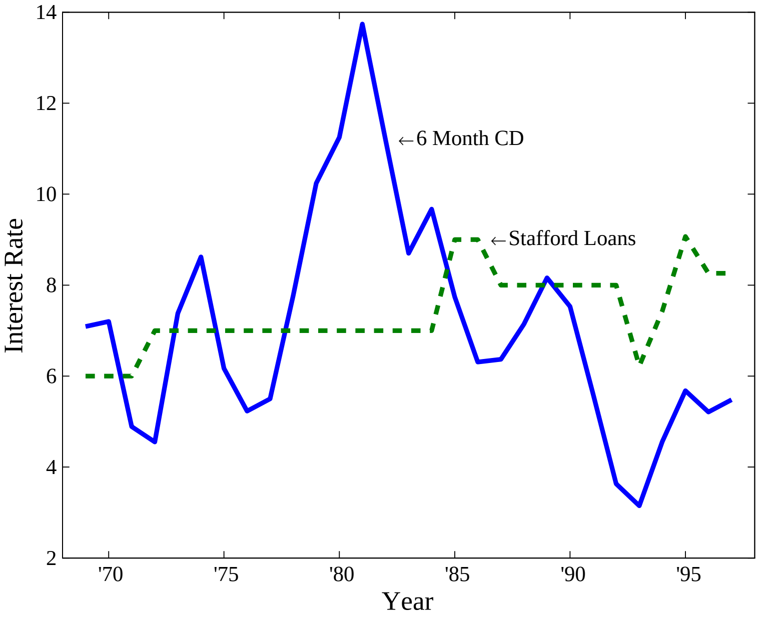

Fig. 6. Interest rates on student loans and on government bonds. Source: U.S. Department of Education and Federal Reserve.

decision.[23] But Cameron and Taber conclude that their results do not imply "that credit market constraints would not exist in the absence of the assortment of private and government programs currently available. Instead, [the] findings show that given the large range of subsidies to education that currently exist, there is no evidence of underinvestment in schooling resulting from credit access".

4.2. The skill premium

We have argued that financial constraints limiting access to education affect the informational value of education and hence the returns to education. How important an effect is this? A full empirical investigation of the significance of financial constraints on wage inequality is beyond the scope of this paper. However, we believe the mechanism discussed above has some interest, given the patterns of inequality observed in the data.[24]

The basic facts about wage inequality are agreed upon. The college skill premium in the United States rose in the 1950s, flattened for the first half of the 1960s before rising again

[23] Other examples include Carneiro and Heckman (2002), Shea (2000), and Keane and Wolpin (2001).

[24] A careful reader will note that the source of the inequality in the model is that the wages of the skilled are constant while the wages of the unskilled decline. The constant wage of the skilled is contrary to evidence, although we can change the model to include ability growth over time to capture this and maintain our basic results. The decline in the wages of the unskilled that our model displays is quite interesting; as we discussed in the Introduction, this decline is an empirical fact that most theoretical models are unable to capture.

in the second half of that decade, fell in the 1970s, and began a very steep ascent around 1979.[25] In the standard labor supply/labor demand model, increasing relative demand for skilled labor can explain the simultaneous increase in the supply of college graduates and an increasing skill premium. A common explanation for the increase in relative demand is skill-biased technological change; but as Krugman (2000) points out, the evidence for skill-biased technological change is indirect: "...it is essentially inferred from the fact that the relative wage and the relative employment of the highly educated have moved in the same direction". The innovation of our model is that it generates an increasing skill premium via a supply shift.

One key element of our theory is that perceptions of the ability of educated workers have changed over time as a result of enhanced opportunities for higher education. Although we have no hard evidence for this, anecdotal evidence exists. In a 1960 report to the American Economic Association (Becker, 1960), Gary Becker wrote: "The available evidence [indicates] that many who do not go to college rank higher in I.Q. or grades than many who do". Forty years later, Stephen Rose, a senior economist at the Educational Testing Service illustrated how much has changed: "You need a bachelor's degree just to apply for the best jobs. That is how it should be for doctors, lawyers, scientists, engineers, computer specialists. But look at middle-level managers. In 1960, only 40 percent had a bachelor's degree and today it is 80 percent".[26]

There are several reasons to question our argument. First, our model suggests that inequality should have risen throughout the entire postwar period, as financial assistance for higher education became an integral part of the education decision. In fact, the history of inequality in the postwar era is more nuanced, as mentioned above. Obviously, this could be a failure of the "all else equal" assumption of our model. Another issue is that our model says that any reduction in financial constraints should increase wage inequality for the cohorts receiving education now, but not for cohorts who have already reached maturity and cannot easily change their education status. In general as time progresses, a larger and larger fraction of cohorts take advantage of the lower constraints, and overall wage inequality increases as well. Card and Lemieux (2001) argue that we can account for much of the sharp increase in the college premium since 1980 by the youngest cohorts, a result consistent with our theory. In addition, there is a spike upwards in the skill premium from 1959 to 1970 for the youngest cohort, while the older cohort's premium remains flat.[27] Card and Lemieux, however, argue that demand for skilled labor outpaced increasing educational attainment.

Second, our model predicts a negative relationship between college tuition (T) and the skill premium, which contradicts cross-country evidence. Tuition costs are generally higher in the United States than in other OECD countries.[28] In particular, well-known

[25] For graphs and analysis see Goldin and Margo (1992), Katz and Murphy (1992), and Katz and Autor (1999).

[26] As quoted in *The New York Times*, July 23, 2000 (Uchitelle, 2000).

[27] See Fig. 1 in Card and Lemieux (2001).

[28] Even with universal access to universities, there may be hidden costs to students though: opportunity costs and living expenses. In many countries, it is difficult to find credit markets that cover these costs, although several European countries have established funding for these expenses through grants and loans (see OECD, 1990).

private colleges and universities in the United States often charge tuition that exceeds that of even public universities in the United States by an order of magnitude. At the same time, the skill premium in the United States exceeds that of almost all other OECD countries. (See Fig. 7) While we cannot fully account for the evidence, we offer insight first on why other countries may not match the assumptions of our model, and second on implications of our model that might begin to explain the differences.

As we discussed in Section 3.2, a large reduction in tuition may have substantially different effects than reductions in the interest rate. One possibility is the violation of our critical assumption in Eq. (3). This could force a switch to a pooling equilibrium, starting different dynamics than the ones we describe. Moreover, subsidizing tuition could induce some form of rationing of educational resources. This may come in the form of entrance exams (which skew toward favoring those who are well off) or through personal connections and does not readily fit into our model of signaling.[29]

Two interesting features of our model may partially explain the observed relationship between the skill premium and tuition. First, Europeans countries have lower tuition but also have highly progressive tax codes. According to our model, progressive taxes depress college attainment and therefore reduce pretax wage inequality. Second, our model allows for multiple stable equilibria. Fig. 2 shows a situation with both a high equality and a high inequality equilibrium in spite of identical levels of tuition. These two factors depend on the level of education being correlated with the skill premium. Looking at a comparison of Europe and the United States, this is not entirely clear, although a restriction to G7 countries (underlined in Fig. 7) displays this pattern.

4.3. Intergenerational mobility

Our analysis can provide insight into intergenerational wealth mobility. The literature on mobility is increasing and Charles and Hurst (2003) provide the first paper that looks at the correlation of wealth across generations (previous papers only look at the correlation of earnings). Nevertheless, there are limitations to empirical testing: Charles and Hurst (2003) use the PSID and have in their sample only 1491 parent–child pairs. This is actually a large number—Solon (1992) uses only 348 pairs for his analysis of earnings mobility. Hence we do not perform any empirical analysis and only offer potential avenues of investigation.

First, assume that we are in Case 2, where the economy increases the amount of education and high wage employees and decreases the wage of the uneducated population. In that case, among the high-ability types, all income groups except for the most wealthy pass on a larger bequest to their children than they received. Not only do the most wealthy families move down in wealth, but their rate of decrease gets slower with each successive generation (as some of them get absorbed by $\bar{b}$). The rate of downward mobility is

[29] A recent highly publicized illustration of the value of connections came from Britain, where a young woman from a public high school was denied acceptance to Oxford while at the same gaining admission to Harvard. In the ensuing scandal, the following fact surfaced: “Among pupils with the same qualifications, applicants from private schools are 25 times more likely to gain admission to [Oxford or Cambridge] than those from state schools” (Pollard, 2000).

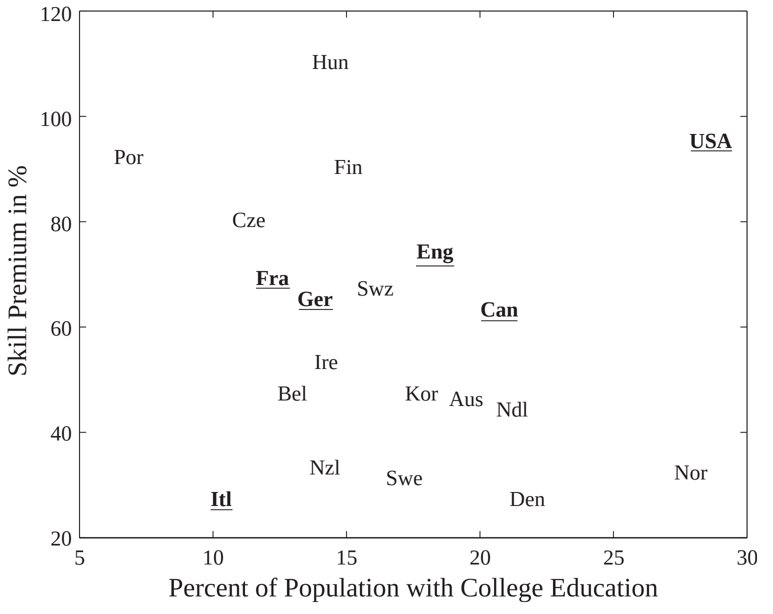

Fig. 7. Skill premium versus college-educated share of population, ages 25 to 64, OECD countries, 1997 to 2001, G-7 countries (except Japan for which there was no data) are underlined. Notes: (1) skill premium defined as percentage by which earnings of college-educated workers exceed those of high school graduates. (2) For college educated workers, we use the OECD definition, "Tertiary Education Type A". (3) For details, see the source, Table A14.1 of "Education at a Glance 2003" at www.oecd.org.

something interesting to test, but could involve great difficulty given that it involves observing a minimum of three generations.

Second, our paper makes the case that the elasticity of child wealth with respect to parental wealth should be different for different wealth groups. Specifically, the middle group (educated but borrowing) is more mobile in terms of wealth than the rich and the poor and should have the highest elasticity. This is evident from the slopes of the bequest function for high-ability workers: the slope is $(1-\alpha)(1+r_B)$ for middle types and is $(1-\alpha)(1+r_L)$ for other types. This could be tested by regression techniques, but may suffer from the lack of available data points. The usual regression which involves regressing the log of child's wealth on the log of parent's wealth could be augmented with a quadratic parent's wealth term to add curvature and see whether there is a difference in the elasticities for different wealth groups.

5. Conclusion

In this paper, we argue that reducing financial constraints for postsecondary education can increase wage inequality. We use a dynamic approach based on job market signaling, a mechanism that has been unexplored in recent work on wage inequality. A reduction in the interest rate increases the number of the poor who get educated in steady state, lowering the average ability of the uneducated pool, and therefore increasing the wage gap. In the last 60 years, two events (the G.I. Bill and the Higher Education Act) significantly reduced the cost of higher education, while many subsequent acts have further increased its overall accessibility.

Our work suggests two natural directions for future research. First, researchers have identified many factors that, in theory, might affect the relationship between wages and education. One natural question to ask is how these other factors interact with the mechanism we have described here. Second, while we have provided some stylized facts that are consistent with the ideas in this paper, formal empirical tests can provide evidence on how changing financial opportunities have affected wage inequality.

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Appendix A

A.1. Proof of Proposition 1

Proof. $b^*(w^e - w^n)$ is continuous. By assumption, $P(\cdot)$ is continuous, then $f(\cdot)$ is continuous. The unskilled wage must lie in a convex, compact set. The maximum skill premium occurs when all high-ability persons become educated and equals $q^H - q^L$. The minimum skill premium occurs when no high-ability persons become educated and equals $q^H - \bar{q}$. Therefore, by the Brouwer Fixed Point Theorem, an equilibrium exists. Since $\partial P/\partial b^* \neq 0$ for all b^*, we know that at any equilibrium, $\partial f/\partial T \neq 0$ and $\partial f/\partial r_B \neq 0$. Thus, rank $(Df(w^e - w^n, T, r_B)) = 1$. By the Transversality Theorem (Proposition 17.D.3 in Mas-Colell et al., 1995), for almost every choice of T, $r_B \partial f(w^e - w^n, T, r_B)/\partial w^e - w^n \neq 0$. By the implicit function theorem, equilibrium $w^e - w^n$ depends differentiably on T and r_B. Now, we show that at least one of the regular equilibria must be stable. Now, consider the minimum possible equilibrium price. Assumption (2) in the Proposition implies that at the minimum possible price, we have excess supply. By continuity and Assumption (2) again we know that at that equilibrium, a decrease in prices leads to excess supply, and by regularity we know that an increase in prices leads to excess demand. So, the minimum price equilibrium must be stable. □

A.2. Mutations

Given transition probabilities λ^{H} and λ^{L}, the uneducated wage is defined as w_t^{n}=:

$$\frac{q^{\mathrm{L}}\left[N_{t-1}^{\mathrm{L}}\lambda^{\mathrm{L}}+N_{t-1}^{\mathrm{H}}\left(1-\lambda^{\mathrm{H}}\right)\right]+q^{\mathrm{H}}\left[N_{t-1}^{\mathrm{L}}\left(1-\lambda^{\mathrm{L}}\right)P_{t-1}^{\mathrm{L}}\left(b_{t-1}^{*}\right)+N_{t-1}^{\mathrm{H}}\lambda^{\mathrm{H}}P_{t-1}^{\mathrm{H}}\left(b_{t-1}^{*}\right)\right]}{1-N_{t-1}^{\mathrm{L}}\left(1-\lambda^{\mathrm{L}}\right)\left(1-P_{t-1}^{\mathrm{L}}\left(b_{t-1}^{*}\right)\right)-N_{t-1}^{\mathrm{H}}\lambda^{\mathrm{H}}\left(1-P_{t-1}^{\mathrm{H}}\left(b_{t-1}^{*}\right)\right)} \tag{12}$$

where N_{t-1}^{q} is the number of type q people at time $t-1$ and $P_{t-1}^{q}(b)$ is the distribution of bequests from parents of type q to children living in time t. The uneducated wage equals the expectation of ability of an uneducated worker, given the transitions between types and the bequest distributions. Furthermore, we can solve the difference equations for transitions between types to find that $N_t^{\mathrm{L}}=-\left(\lambda^{\mathrm{H}}+\lambda^{\mathrm{L}}-1\right)^t\left(\pi-\frac{1-\lambda^{\mathrm{L}}}{2-\lambda^{\mathrm{H}}-\lambda^{\mathrm{L}}}\right)+\frac{1-\lambda^{H}}{2-\lambda^{\mathrm{H}}-\lambda^{\mathrm{L}}}$ and $N_t^{\mathrm{H}}=\left(\lambda^{\mathrm{H}}+\lambda^{\mathrm{L}}-1\right)^t\left(\pi-\frac{1-\lambda^{\mathrm{L}}}{2-\lambda^{\mathrm{H}}-\lambda^{\mathrm{L}}}\right)+\frac{1-\lambda^{\mathrm{L}}}{2-\lambda^{\mathrm{H}}-\lambda^{\mathrm{L}}}$. Lastly, we define the education decision as in Section 2.2. We make the following simplifying assumption in order to examine properties of a solution to this type of dynamics: $\lambda^{\mathrm{H}}+\lambda^{\mathrm{L}}=1$. We can call this the zero-correlation case, that is, the probability of having a type q child is the same for both types of parents.

Since $\lambda^{\mathrm{H}}+\lambda^{\mathrm{L}}=1$, for all t, $N_t^{\mathrm{L}}=1-\lambda^{\mathrm{H}}$ and $N_t^{\mathrm{H}}=1-\lambda^{\mathrm{L}}$. Note that from Eq. (12), $w_t^{\mathrm{n}}=(q^{\mathrm{L}}\lambda^{\mathrm{L}}+q^{\mathrm{H}}Y)/(\lambda^{\mathrm{L}}+Y)$ (where $Y=N^{\mathrm{L}}(1-\lambda^{\mathrm{L}})P_{t-1}^{\mathrm{L}}(b_{t-1}^{*})+N^{\mathrm{H}}\lambda^{\mathrm{H}}P_{t-1}^{\mathrm{H}}(b_{t-1}^{*})$). This is increasing in Y since $q^{\mathrm{L}}<q^{\mathrm{H}}$. We fix some time t, and examine the change in Y at time t+1. Let $\Delta P^{\mathrm{L}}=P_t^{\mathrm{L}}(b_{t-1}^{*})-P_{t-1}^{\mathrm{L}}(b_{t-1}^{*})$ and analogously $\Delta P^{\mathrm{H}}=P_t^{\mathrm{H}}(b_{t-1}^{*})-P_{t-1}^{\mathrm{H}}(b_{t-1}^{*})$. Taking into account all of the inflows and outflows:

$$\Delta P^{\mathrm{H}}=\frac{1}{N^{\mathrm{H}}}\left\{-N^{\mathrm{H}}\left(1-\lambda^{\mathrm{H}}\right)P_{t-1}^{\mathrm{H}}(b_{t-1}^{*})+N^{\mathrm{L}}\left(1-\lambda^{\mathrm{L}}\right)P_{t-1}^{\mathrm{L}}(b_{t-1}^{*}+\varepsilon_1)\right.$$
$$\left.+N^{\mathrm{H}}\lambda^{\mathrm{H}}\left(P_{t-1}^{\mathrm{H}}(b_{t-1}^{*}+\varepsilon_2)-P_{t-1}^{\mathrm{H}}(b_{t-1}^{*})\right)\right\},$$

$$\text{and } \Delta P^{\mathrm{L}}=\frac{1}{N^{\mathrm{L}}}\left\{-N^{\mathrm{L}}\left(1-\lambda^{\mathrm{L}}\right)P_{t-1}^{\mathrm{L}}(b_{t-1}^{*})+N^{\mathrm{H}}\left(1-\lambda^{\mathrm{H}}\right)P_{t-1}^{\mathrm{H}}(b_{t-1}^{*}+\varepsilon_2)\right.$$
$$\left.+N^{\mathrm{L}}\lambda^{\mathrm{L}}\left(P_{t-1}^{\mathrm{L}}(b_{t-1}^{*}+\varepsilon_1)-P_{t-1}^{\mathrm{L}}(b_{t-1}^{*})\right)\right\}$$

First, assume that $b_{t-1}^{*}<\tilde{b}$. Then, $\varepsilon_1=\frac{b_{t-1}^{*}(1-(1-\alpha)(1+r))}{(1-\alpha)(1+r)}-\frac{w^{\mathrm{n}}}{1+r}>0$ and $\varepsilon_2=\frac{b_{t-1}^{*}(1-(1-\alpha)(1+i))}{(1-\alpha)(1+i)}-\frac{w^{\mathrm{e}}}{1+i}+T>0$, since more people are shifting downwards towards b_{t-1}^{*}. Define $\Delta Y=N^{\mathrm{L}}(1-\lambda^{\mathrm{L}})\Delta P^{\mathrm{L}}+N^{\mathrm{H}}\lambda^{\mathrm{H}}\Delta P^{\mathrm{H}}$. It is then straightforward to show that, given $\lambda^{\mathrm{H}}+\lambda^{\mathrm{L}}=1$, $\Delta Y>0$. This implies that $w_t^{\mathrm{n}}(b_{t-1}^{*})>w_{t-1}^{\mathrm{n}}$, which, using the logic from the no-mutations case (and again assuming a unique equilibrium), implies that $b_t^{*}>b_{t-1}^{*}$.

Next, assume that $b_{t-1}^{*}>\tilde{b}$. Now $\varepsilon_1<0$ and $\varepsilon_2<0$, since people are shifting towards from b_{t-1}^{*}. This produces the opposite effect, such that $\Delta Y<0$ and hence $b_t^{*}<b_{t-1}^{*}$.

Lastly, assume that $b_{t-1}^{*}=\tilde{b}$. At this point, $\varepsilon_2=0$, since no high-ability persons will flow above or below b_{t-1}^{*}. Low-ability persons still flow downwards, however, making $\varepsilon_1>0$. In this case, $\Delta Y>0$ and $b_t^{*}>b_{t-1}^{*}$.

We can now discuss the results listed in the proposition. Movements in the threshold for education b_t^* are similar to the no-mutations case for $b_{t-1}^*<\tilde{b}$ and $b_{t-1}^*>\tilde{b}$. The lack of stability at $b_{t-1}^*=\tilde{b}$ is different and leads us to the pooling steady state of no education. If all high-bequest individuals have been pushed down the bequest distribution, then $P_{t-1}^{\mathrm{H}}(b_{t-1}^*)=P_{t-1}^{\mathrm{L}}(b_{t-1}^*)=1$ at some time t. At this point $\Delta Y=0$, and the wage and cutoff will stay the same ($w^{\mathrm{n}}=\bar{q}$). This can happen at any point where, in the period before the steady state begins, the last high-bequest individuals inch down the distribution, that is, where $b\leq\tilde{b}$.

In the case of complete separation, $P_{t-1}^{\mathrm{H}}(b_{t-1}^*)=P_{t-1}^{\mathrm{L}}(b_{t-1}^*)=0$ at some time t. This implies that $b_t^*=b_{t-1}^*$ and $\Delta Y=0$, meaning that the uneducated pool contains no highly-skilled workers and $w^{\mathrm{n}}=q^{\mathrm{L}}$.

This type of convergence may not occur, for if $b_{t-1}^*<\tilde{b}$, and there still remain individuals at the higher end of the bequest distribution, we have shown that there is no bequest b that is stable. In addition, all of the movement is directed towards $\tilde{b}$, but $\tilde{b}$ is not a stable point.

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