Skill Biased Technological Change, the Deterioration of College Graduates, and the Evolution of the Skill Premium (Draft)

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Abstract

This simple signaling model with indivisible education shows that skill biased technological change (SBTC) explains both the sharp increase in wage inequality in the 1980s as well as the relative constant college premium in the 1990s in the US. If the productivity of skilled agents is moderate, only talented workers acquire a college degree, and SBTC has a direct effect on the wages of these workers. If SBTC continues, the labour market enters a hybrid equilibrium in which an increasing number of less skilled workers studies. This dilutes the skill composition among college graduates and slows down the increase in wage inequality. Moreover, I show that conditional on the level of productivity, SBTC can improve or reduce market efficiency. A dynamically adjusted tuition fee can restore efficiency.

JEL classification: J24, J31

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1 Introduction

In the 1980s, wage inequality between U.S. college graduates and high school graduates rose significantly, often attributed to skill biased technological change (SBTC). For example, Krueger (1993) shows that "the expansion in computer use in the 1980s can account for one-third to one-half of the increase in the rate of return to education". However, wage inequality stabilised in the 1990 despite continuing technological progress. Therefore, Card and DiNardo (2002) conclude that skill biased technological change "falls short as unicausal explanation for the evolution of the U.S. wage structure in the 1980s and 1990s".

I use a simple model in the spirit of Spence (1973) to show that SBTC can well explain the evolution of wage inequality once we consider signaling and endogenous investment in indivisible education. If the productivity of high skilled workers is relatively low, the economy is in a separating equilibrium in which only the most able high school graduates acquire a college degree. These workers benefit fully from skill biased technological change, reflecting the strong increase in wage inequality in the 1980s. However, as SBTC continues, the economy enters a hybrid equilibrium in which an increasing number of less able workers acquires a college degree. This dilutes the productivity of college graduates and slows down the increase in the wage inequality.

A significant strand of literature discusses the dynamics of inequality and technological change. Acemoglu (2002) provides a great survey and concludes that "technical change has been skill-biased during the past sixty years" and that "the evidence also points to an acceleration in skill bias during the past few decades". He attributes a significant share of the change in wage inequality to change in "the organization of the labor market" (Acemoglu, 2002). There is also evidence that the skill composition within educational groups affects wage inequality. For instance, Chay and Lee (2000) show that "the rise in the return to ability can account for at most 30-40% of the observed rise in the college premium for young workers" in the 1980s and suggest that "future research might attempt to obtain credible estimates of changes in relative worker quality over time". Juhn et al. (1993) suggest that "the trend toward greater wage inequality is attributable primarily to increases in the premia on both unobserved and observed (such as education) dimensions of skill, with the majority of the increase over the period due to the unobserved component". Lemieux

(2006) focuses on within-group inequality and argues that "increases in the return to unobserved skills account for no more than 25 percent of the overall increase in wage inequality over the last three decades" and "that a large fraction of the 1973-2003 growth in residual wage inequality is due to composition effects linked to the secular increase in experience and education, two factors associated with higher within-group wage dispersion".

In this paper, I also find that skill biased technological change has a non–monotonic effect on efficiency. If productivity of skilled workers raises continuously, the economy first experiences a period of overeducation of high skilled labour, followed by a period of efficient investment in human capital. If SBTC continues, we observe overeducation of low ability workers. A carefully designed and dynamically adjusted proportional income tax can be used to reinstall efficiency. However, any measure needs to consider the non-monotonic dynamic effects described above.

The remainder of this paper is structured as follows: Section 2 explains the model framework, and section 3 derives the equilibrium. In chapter 4, I discuss the effects of skill biased technological change on wage inequality as well as efficiency and presents a numerical example. Section 6 illustrates concludes.

2 The Model

Consider an economy that is populated by two types of workers who differ in their innate ability θ_i. The exogenous fraction q of workers is of type h and has high ability θ_h, the remainder is of type l and has low ability $\theta_l < \theta_h$. Each individual worker knows her own type, but the type cannot be observed by a potential employer as in Spence (1973). Workers enter the model after graduating from high school and decide on their tertiary education e_i, which they can condition on their own type i. In particular, the worker has the discrete choice to acquire a college degree ($e_i = 1$) or to abstain from going to college ($e_i = 0$), thus $e_i \in \{0, 1\}$ for $i = h, l$. As in the standard signaling model by Spence (1973), education is more costly for workers with low ability, e.g. because they have to sacrifice more leisure for their studies than more able students. Therefore, θ_h-workers must pay c in sweat costs for a college degree, while it costs λc with $\lambda > 1$ for θ_l-workers.

In contrast to the textbook model, a worker's productivity does not only depend on her innate ability θ_i, but also education has a positive effect on productivity. A worker with education e_i has the *knowledge* $s(e_i)$, and a college degree raises the knowledge from $s(0)$ to $s(1) > s(0)$. I further assume complementarities between ability and knowledge. In particular, a worker with innate ability θ_i and knowledge $s(e_i)$ has the productivity

$$p(\theta_i, s(e_i)) = \theta_i s(e_i).$$

Firms observe the formal education of a worker e_i, but they cannot directly determine the worker's individual ability θ_i. Therefore, firms use the worker's education decision to infer information about that worker's productivity, knowing that studying is more costly for workers with low ability. In the competitive labour market, Bertrand competition among firms gives rise to wages equal to the expected productivity of an applicant,

$$w = E[\theta_i]s(e_i).$$

$E[\theta_i]$ is determined via a signaling game, in which firms adjust their expectations to the observed education. We call $\boldsymbol{\mu} = (\mu_1, \mu_0)$ the belief system of a firm, where μ_j denotes the belief that a worker with education j is of type h, that is, has high ability θ_h. Then,

$$E[\theta_i] = \mu_{e_i}\theta_h + (1 - \mu_{e_i})\theta_l, \text{ so} \tag{1}$$

$$w(e_i, \boldsymbol{\mu}) = [\mu_{e_i}\theta_h + (1 - \mu_{e_i})\theta_l]s(e_i). \tag{2}$$

Note that the wage of a worker $w(e_i, \boldsymbol{\mu})$ depends on his knowledge e_i and the firms' beliefs $\boldsymbol{\mu}$, but not directly on his type (which of course may well affect his choice of e_i).

3 The Equilibria

3.1 Definition

$\Phi = \Phi(\boldsymbol{e}, \boldsymbol{\mu})$ is a Perfect Bayesian Equilibrium (PBE) if it satisfies the following conditions:

Workers choose an optimal strategy $\boldsymbol{e} = (e_h, e_l)$ that maximises their expected wage net of education costs, and firms form beliefs $\boldsymbol{\mu} = (\mu_1, \mu_0)$ that are consistent with $\boldsymbol{e}$ and maximise their expected profits by offering wages that are determined by (2).

3.2 Separating Equilibria

In a pure separating equilibrium, workers of different types choose different levels of education. Both levels of education are observed in equilibrium, so μ_1 and μ_0 are determined by Bayes' Rule. In principle, there could be two different separating equilibria. In the first one, $\Phi = ((1,0),(1,0))$, all workers with high ability and no worker with low ability acquire a college degree. This is in fact a PBE if no worker with high ability can improve his payoff by deviating to $e_h = 0$,

$$\begin{aligned} w(1,(1,0)) - c &\geq w(0,(1,0)), \text{ so} \\ \Omega_h^s \equiv \theta_h s(1) - \theta_l s(0) &\geq c. \end{aligned} \tag{3}$$

A worker with high ability who deviates to $e_h = 0$ saves the costs of education, but he has the lower knowledge $s(0)$ and suffers from the low expected ability level of non-graduates θ_l, even though he in fact has the high ability θ_h. It is also necessary that a worker with low ability cannot gain by deviating to $e_l = 1$,

$$\begin{aligned} w(0,(1,0)) &\geq w(1,(1,0)) - \lambda c, \text{ so} \\ \Omega_l^s \equiv \frac{1}{\lambda}\left[\theta_h s(1) - \theta_l s(0)\right] &\leq c. \end{aligned} \tag{4}$$

Combining the two inequalities we obtain

$$c \leq \theta_h e(1) - \theta_l s(0) \leq \lambda c. \tag{5}$$

This separating equilibrium exists if the costs of education are sufficiently low such that it is optimal for high ability workers to study, but it is too costly for low ability workers to mimic high ability.

In principle, there could also be a counterintuitive equilibrium $\Phi = ((0,1),(0,1))$ in which untalented workers acquire eduction and talented ones do not. This would require for a high ability worker

$$\begin{aligned} w(0,(0,1)) &\geq w(1,(0,1)) - c, \\ \theta_h s(0) - \theta_l s(1) &\leq c, \end{aligned}$$

and for a low ability worker

$$\begin{aligned} w(1,(0,1)) - \lambda c &\geq w(0,(0,1)), \\ \frac{1}{\lambda}\left[\theta_l s(1) - \theta_h s(0)\right] &\geq c. \end{aligned}$$

Combining them, we obtain

$$\lambda c \leq \theta_l s(1) - \theta_h s(0) \quad \leq \quad c \tag{6}$$

However, as it is more expensive for low ability workers to obtain a college degree ($\lambda c > c$) this inequality can never hold and there exists no separating equilibrium with $\Phi = ((0,1),(0,1))$.

3.3 Pooling Equilibria

3.3.1 Pooling I – no Education

Next consider pure pooling equilibria in which all workers independent of their type choose the same level of education. First, we check for potential equilibria in which no worker acquires education, $\Phi = ((0,0),(\mu_1,q))$. While $\mu_0 = q$ is determined by Bayes rule, μ_1 is not restricted as $e_i = 1$ is not observed on the equilibrium path. This is in fact a PBE if neither workers with high nor workers with low ability want to deviate to $e_i = 1$, thus

$$\begin{aligned} w(0,(\mu_1,q)) &\geq w(1,(\mu_1,q)) - c \\ \Omega_n^p \equiv [\mu_1\theta_h + (1-\mu_1)\theta_l]s(1) - [q\theta_h + (1-q)\theta_l]s(0) &\leq c \end{aligned} \tag{7}$$

$$\begin{aligned} w(0,(\mu_1,q)) &\geq w(1,(\mu_1,q)) - \lambda c \\ \frac{1}{\lambda}[[\mu_1\theta_h + (1-\mu_1)\theta_l]s(1) - [q\theta_h + (1-q)\theta_l]s(0)] &\leq c \end{aligned} \tag{8}$$

If (7) is satisfied, (8) must also hold: the cost of deviating to a master is lower for workers with high ability, thus if they do not deviate, the workers with low ability also do not.

3.3.2 Pooling II – Education

Now consider a candidate equilibrium with $\Phi = ((1,1),(q,\mu_0))$, so every worker goes to college. Again, while $\mu_1 = q$ is on the equilibrium path and thereby determined by Bayes Rule, $e_i = 0$ is never observed in such an equilibrium, thus μ_0 is, in principle, not restricted,

$$\begin{aligned} w(1,(q,\mu_0)) - c &\geq w(0,(q,\mu_0)) \\ [q\theta_h + (1-q)\theta_l]\, s(1) - [\mu_0\theta_h + (1-\mu_0)\theta_l]s(0) &\geq c \end{aligned} \tag{9}$$

$$\begin{aligned} w(1,(q,\mu_0)) - \lambda c &\geq w(0,(q,\mu_0)) \\ \Omega_d^p \equiv \frac{1}{\lambda}\left[[q\theta_h + (1-q)\theta_l]s(1) - [\mu_0\theta_h + (1-\mu_0)\theta_l]s(0)\right] &\geq c \end{aligned} \tag{10}$$

A master is more expensive for low ability workers, thus (9) is always satisfied if (10) holds. In a nutshell, the fraction of high ability workers q and the benefits of education must be sufficiently high, while the costs of a master for low ability workers must be sufficiently low to establish this equilibrium.

3.4 Hybrid Equilibria

In the first potential hybrid equilibrium, all high ability workers and the endogenous fraction h_l of low ability workers acquire education, $\Phi = ((1, h_l), (\mu_1^l(h_l), 0))$. Both levels of education are observed in equilibrium and μ_i is determined by Bayes Rule. Any worker who does not study must be of the low–ability–type, so $\mu_0 = 0$. There are q high ability workers and $(1-q)h_l$ low ability workers with a college degree, thus probability that a worker with a degree has high ability is

$$\mu_1^l(h_l) = \frac{q}{q + (1-q)h_l} \geq q \text{ for } 0 \leq h_l \leq 1.$$

If low ability workers acquire two different levels of education in equilibrium, these two actions must promise the same expected payoff, otherwise the workers would not play a mixed strategy. h_l must satisfy

$$\begin{aligned} w(1,(\mu_1^l(h_l),0) - \lambda c &= w(0,(\mu_1^l(h_l),0)), \text{ so} \\ \left[\frac{qF(\theta_h^l)}{q+(1-q)h_l} + \frac{(1-q)h_l\theta_l}{q+(1-q)h_l}\right] s(1) - \lambda c &= \theta_l s(0). \end{aligned} \tag{11}$$

h_l is decreasing in c as a costlier education must be compensated by a higher skill premium, that is, a lower fraction of low ability workers with a degree h_l.

In the second potential hybrid equilibrium, the endogenous fraction h_h of the high ability workers study, while the remainder of the high ability workers and all low ability workers abstain from further education, $\Phi = ((h_h, 0), (1, \mu_0^h(h_h)))$. Then, analogous to the previous equilibrium, $\mu_1 = 1$, and

$$\mu_0^h(h_h) = \frac{(1-h_h)q}{(1-h_h)q + (1-q)} \leq q \text{ for } 0 \leq h_h \leq 1.$$

In order to make high ability workers indifferent between the two levels of education, h_h must satisfy

$$
\begin{aligned}
w(1,(1,\mu_0^h)-c &= w(0,(1,\mu_0^h)) \\
\left[\frac{(1-h_h)q\theta_h}{(1-h_h)q+(1-q)}+\frac{(1-q)\theta_l}{(1-h_h)q+(1-q)}\right]s(0) &= \theta_h s(1)-c. \qquad (12)
\end{aligned}
$$

3.5 The Social Planner

In contrast to the textbook model by Spence (1973), education raises productivity and investment in human capital might be efficient for one or both types of workers in equilibrium. Consider a social planner who chooses the fraction of high ability (low ability) workers who acquire education σ_h (σ_l) in order to maximise the total output in the economy, net of the costs of education. The the planner's problem can be written as

$$
\begin{aligned}
\max_{\sigma_h,\sigma_l} \quad & W(\sigma_h,\sigma_l) \text{ with} \\
W(\sigma_h,\sigma_l) \;=\; & q\left[\sigma_h\theta_h s(1)-\sigma_h c+(1-\sigma_h)\theta_h s(0)\right] \\
& +(1-q)\left[\sigma_l\theta_l s(1)-\sigma_l\lambda c+(1-\sigma_l)\theta_l s(0)\right].
\end{aligned}
$$

Note that we could also consider the two types separately. The first order conditions are

$$
\begin{aligned}
\frac{\partial W(\sigma_h,\sigma_l)}{\partial\sigma_h} &= q\left[\theta_h s(1)-c-\theta_h s(0)\right]=0 \text{ and} \\
\frac{\partial W(\sigma_h,\sigma_l)}{\partial\sigma_l} &= (1-q)[\theta_l s(1)-\lambda c-\theta_l s(0)]=0.
\end{aligned}
$$

Thus, the social planner prefers to educate workers with high ability if

$$\Omega_h^e \equiv \theta_h s(1)-\theta_h s(0)\geq c \qquad (13)$$

and for with low ability if

$$\Omega_l^e \equiv \frac{1}{\lambda}\left[\theta_l s(1)-\theta_l s(0)\right]\geq c. \qquad (14)$$

The following list summarizes all threshold levels.

$$\begin{aligned}
\Omega_h^s &= \theta_h s(1) - \theta_l s(0), \\
\Omega_n^p &= [\mu_1\theta_h + (1-\mu_1)\theta_l]s(1) - [q\theta_h + (1-q)\theta_l]s(0), \\
\Omega_h^e &= \theta_h s(1) - \theta_h s(0), \\
\Omega_l^s &= [\theta_h s(1) - \theta_l s(0)]/\lambda, \\
\Omega_d^p &= [[q\theta_h + (1-q)\theta_l]s(1) - [\mu_0\theta_h + (1-\mu_0)\theta_l]s(0)]/\lambda, \\
\Omega_l^e &= [\theta_l s(1) - \theta_l s(0)]/\lambda.
\end{aligned}$$

3.6 The Static Equilibrium

Assumption 1: $\lambda > \dfrac{s(1) - \dfrac{\theta_l}{\theta_h}s(0)}{s(1) - s(0)} > 1.$

Proposition 1: Under Assumption 1, $\Omega_h^s > \Omega_n^p > \Omega_h^e > \Omega_l^s > \Omega_d^p > \Omega_l^e$.

Ω_h^s is larger than any other threshold because in a separating equilibrium, the profit of education is the largest while the costs of education for θ_h-workers are very low. Ω_l^e is smaller than any other threshold because low ability workers have the highest costs of education, while the social gains of their education are low.

In order to pin down the remaining off equilibrium beliefs in the pooling equilibria we use the divine equilibrium by Banks and Sobel (1987), that is, off-equilibrium beliefs should reflect the incentives of the different types to deviate to that equilibrium. We have already seen that the incentives to deviate from $\Phi = ((0,0),(\mu_1,q))$ are always larger for high ability workers because (7) implies (8). Then a firm should set its off-equilibrium beliefs for this equilibrium to $\mu_1 = 1$, so[1]

$$\Omega_n^p = \theta_h s(1) - [q\theta_h + (1-q)\theta_l]s(0).$$

We use the same approach to fix μ_0 in $\Phi = ((1,1),(q,\mu_0))$: (10) implies (9), thus it is always more beneficial for workers with θ_l to deviate, so $\mu_0 = 0$ and

$$\Omega_d^p = [[q\theta_h + (1-q)\theta_l]s(1) - \theta_l s(0)]/\lambda.$$

It is also straightforward to check that $\Omega_l^s > \Omega_d^p$ and $\Omega_n^p > \Omega_h^e$ (as $\mu_1 > q$).

We can also determine the two different hybrid equilibria in detail. In $\Phi = ((1,h_l),(\mu_1^l(h_l),0))$

[1]The ordering proposed in proposition 1 is also true if we just set $\mu_1 > q$.

$h_l = 0$ if $c = \Omega_l^s$ and $h_l = 1$ if $c = \Omega_d^p|_{\mu_0=0}$. Moreover, neither a pure separating equilibrium nor a pure pooling equilibrium exists for $\Omega_d^p < c < \Omega_l^s$. Then the hybrid equilibrium $\Phi = ((1, h_l), (\mu_1^l(h_l), 0))$ is stable and small "trembles" within the players' strategies do not eliminate this equilibrium.

In the hybrid equilibrium $\Phi = ((h_h, 0), (1, \mu_0^h(h_h)))$ for $c \to \Omega_h^s$, $h \to 0$ and for $c \to \Omega_n^p|_{\mu_1=1}$, $h \to 1$. This hybrid equilibrium exists for $\Omega_n^p < c < \Omega_h^s$, that is, in presence of a (no education) pooling equilibrium and a separating equilibrium. This hybrid equilibrium is not stable as the education of high ability workers is subject to complementarities: if h_h raises just a little bit, the average productivity of uneducated workers declines, making education even more attractive for high ability workers, so we move away from the hybrid equilibrium towards the (pure) separating equilibrium.

Figure 1 depicts the different equilibria conditional on c. For a very costly education system with $c > \Omega_h^s$, no worker acquires education. If costs are in the range $\Omega_l^s < c < \Omega_h^s$, there exists a separating equilibrium, in which only workers with high abilities acquire education. In the range $\Omega_n^p \leq c \leq \Omega_h^s$, this separating equilibrium coexists with the $\Phi = ((0, 0), (\mu_1, q))$ pooling equilibrium and with the instable hybrid equilibrium in which only some high ability workers study.

If c drops further to $\Omega_d^p < c < \Omega_l^s$, neither a (pure) separating equilibrium nor a (pure) pooling equilibrium can exist. A separating equilibrium cannot occur because education is sufficiently cheap such that low ability workers have an incentive to deviate to education and to earn the big wage differential $\theta_h s(1) - \theta_l s(0)$. On the other hand, in a potential pooling equilibrium in which both educate, the benefits of education are strictly lower (at most $[q\theta_h + (1-q)\theta_l]s(1) - [\mu_0\theta_h + (1-\mu_0)\theta_l]s(0)$), so θ_l–workers would deviate from such a pooling equilibrium to no education. The only equilibrium is the hybrid equilibrium $\Phi = ((1, h_l), (\mu, 0))$. For $c < \Omega_d^p$, every worker acquires education.

Efficiency

In the signaling model, the education premium contains the real increase in productivity and, for some equilibria, the value of the separation from the group without education and with a lower expected ability. The second effect can give rise to overeducation. Consider a worker in the separating equilibrium $\Phi = ((1, 0), (1, 0))$.

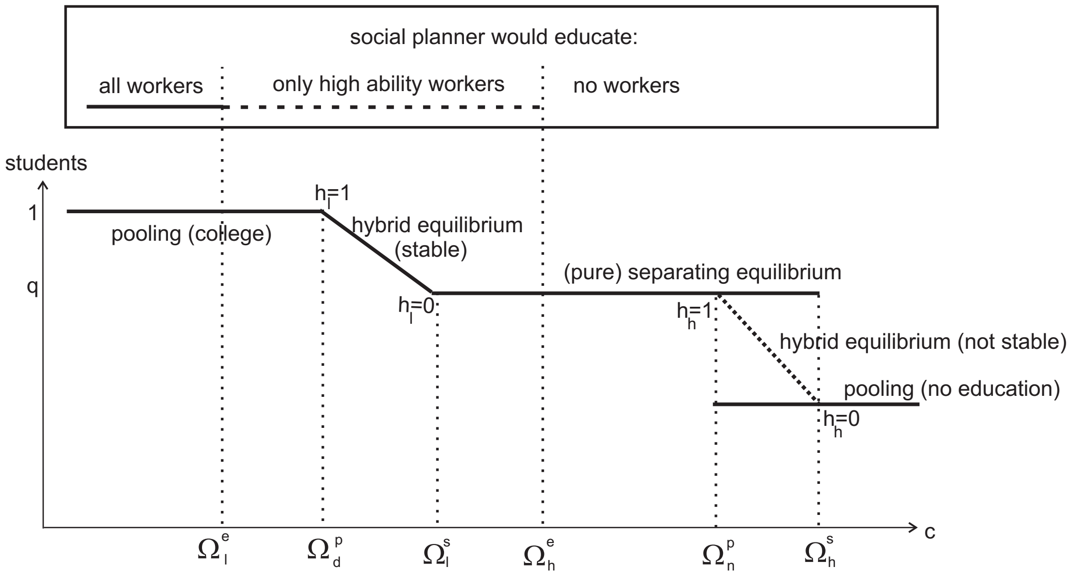

Figure 1: The equilibria

A worker with high ability who deviates to $e_h = 0$ would receive a wage based on the signal of low ability θ_l, which is below his true productivity θ_h. The incentives to avoid this wage drop are inefficiently high and do not reflect the actual difference in productivity. While the social gain of education stems only from the increasing knowledge $\theta_i[s(1)-s(0)]$, the individual gain of education in a separating equilibrium also change the basic wage, that is, $\theta_h s(1) - \theta_l s(0)$. This also holds for overeducation of low ability workers for $\Omega_l^e < c < \Omega_l^s$.

4 Skill Biased Technological Change

I consider skill biased technological change such that the productivity of high ability workers increases faster than the productivity of θ_l-workers. The *effective ability* of a worker with type i is $\theta_i = A_{i,t}\overline{\theta}_h$. The productivity of workers of type i growths at the constant rate g_i with $g_h > g_l$, thus $A_{i,t+1} = (1 + g_i)A_{i,t}$.

Note that skill biased technological change raises $\overline{\lambda}$ in assumption 1 as

$$\overline{\lambda} = \frac{s(1) - \frac{\theta_l}{\theta_h} s(0)}{s(1) - s(0)} \tag{15}$$

$$\frac{\partial \overline{\lambda}}{\partial \theta_h / \theta_l} = \frac{\left(\frac{\theta_l}{\theta_h}\right)^2 s(0)}{s(1) - s(0)} > 0 \text{ with} \tag{16}$$

$$\lim_{\theta_h/\theta_l \to \infty} \overline{\lambda} = \frac{s(1)}{s(1) - s(0)} \tag{17}$$

Therefore, I modify assumption 1 to

Assumption 1a: $\lambda \geq \frac{s(1)}{s(1) - s(0)} > 1$.

For convenience and without loss of generality, I assume that initially $A_{i,0} = 1$, so $\theta_i = \overline{\theta}_i$ for $i = h, l$. In order to understand the different dynamic effects, I first assume $g_l = 0$ and will drop this assumption later in the numerical example. Now technical progress raises $A_{h,t}$. Figure 2 summarises the effect of ongoing skill biased technical change on education for an increase of A from 1 to infinity[2]. This does not affect Ω_l^e as the productivity of low ability workers remains unchanged and the social planner would not modify his optimal education decision for those workers. Any other threshold level will increase: First look at the pure separating equilibrium with $\Omega_h^e < c < \Omega_n^p$. Initially, there is overeducation of high ability workers. With continuing technical progress, the productivity of these workers rises, so at some point, education of high ability workers will become efficient. That is, high ability workers just invest "too early" in their education, because the individual benefits in a separating equilibrium that include the signaling effect exceed the social benefits. In contrast, consider the hybrid equilibrium $\Omega_p^d < c < \Omega_l^s$. An increase in A shifts both thresholds to the right. The wage of workers without a degree remains at θ_l, while even for a given h_l, the wage for graduates raises. In order to satisfy the indifference condition for workers with low ability, the fraction of graduates with low ability h_l must rise, see (11). However, the productivity of the low ability workers did not change, so education of low ability workers reduces efficiency.

[2] Note that the figure would look qualitatively the same if we consider t on the axis of abscissas as $t = (\ln A_t)/[\ln(1 + g)]$.

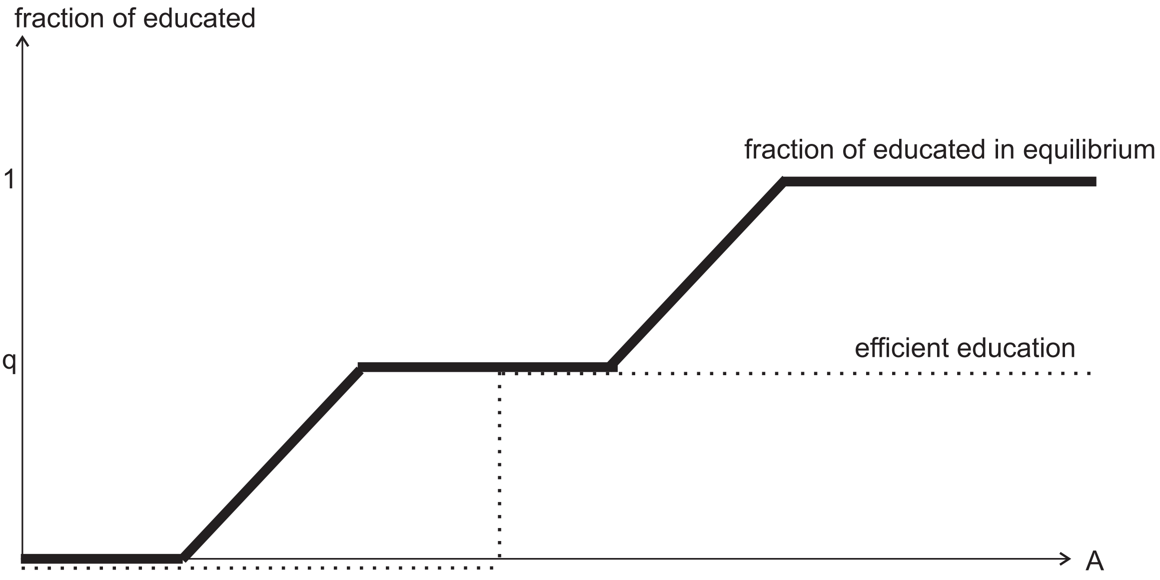

Figure 2: The effect of skill biased technical change on graduates and efficiency

A Numerical Example

I specify $\overline{\theta}_i = 1$, thus $\theta_i = (1 + g_i)^t$. A college degree doubles the productivity of a worker, $s(0) = 1$ and $s(1) = 2$. To keep things simple, we set $c = 3$ and $\lambda = 2$, so θ_l workers must pay 6 units to acquire education. Half of the population has high ability ($q = 0.5$), and $g_h = 0.01$.

Figure 3 illustrates the dynamic effects of SBTC for $g_l = 0$ and for $g_l = 0.002$. With $t = 0$, we start in the pooling equilibrium in which no worker has an incentive to study. As A_t increases, the common wage of all the workers in the pool starts to raise. In the pooling equilibrium, firms cannot condition wages on types, so all workers benefit from that increase. However, once A_t reaches a critical level, the wage differential between high school graduates and potential college graduates (which are expected to be of the θ_h-type) is sufficiently high to cover the costs of education for high ability workers. If more high ability workers study, the average productivity within the group of workers without a college degree drops. At the same time any increase in $A_{h,t}$ raises the salary of the college graduates. This gives rise to a steep increase in wage inequality. In the separating equilibrium, the wage of θ_l-workers grows only at rate g_l, while w_h grows at rate g_h. This is pretty much what we observed in the 1980s. However, once the labour market enters the second hybrid equilibrium, the wage for college graduates grows only at rate g_l as any increase in

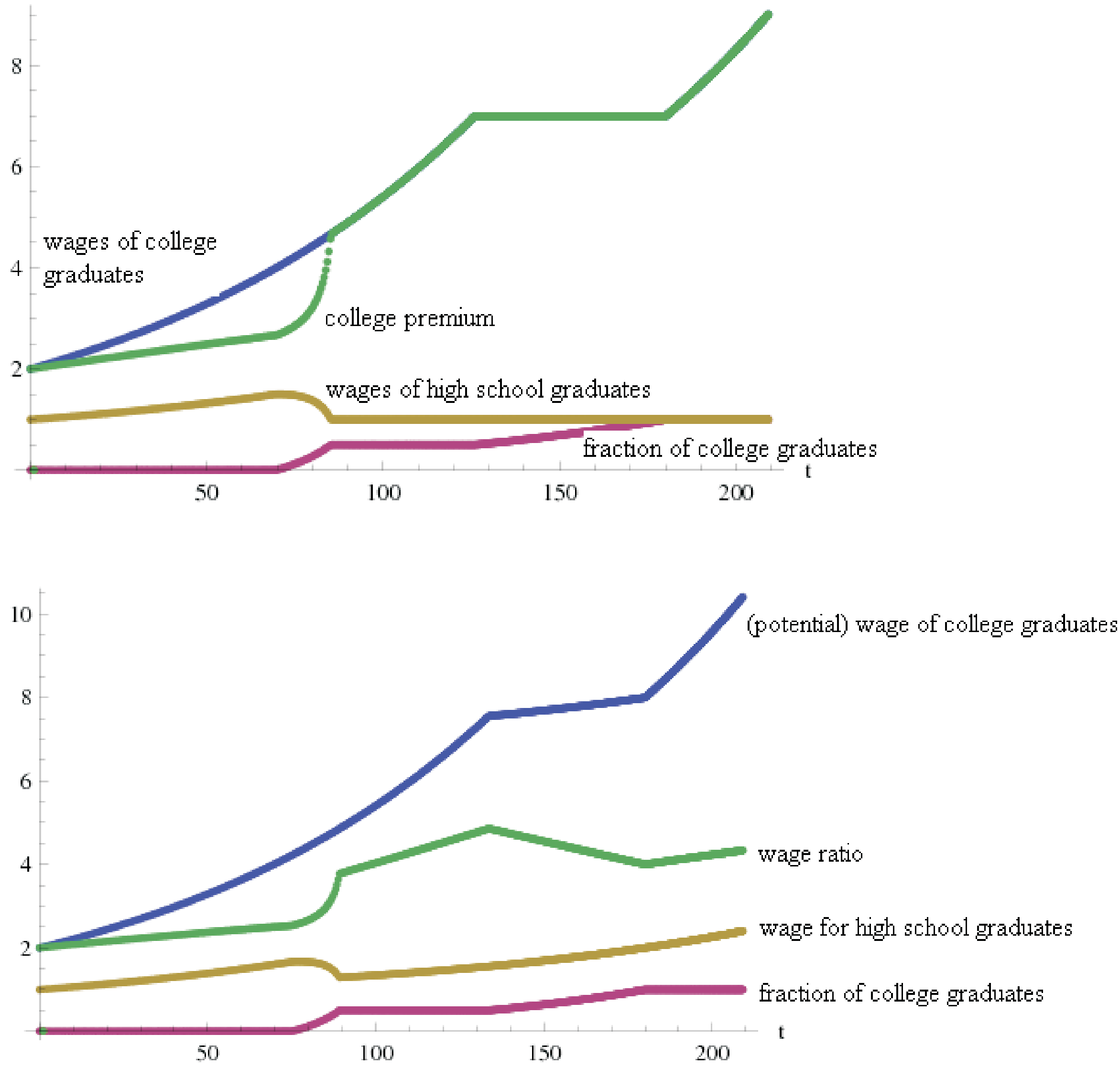

Figure 3: Effect of SBTC on Wages and Education for $g_l = 0$ and $g_l = 0.002$

θ_h is compensated by an increasing number of college graduates with low ability. In this state, the wage premium is constant (for $g_l = 0$) or even slightly declines (for $g_l > 0$) despite the continuing technological progress. This can well explain the evolution of the college premium in the 1980s and the 1990s.

5 Optimal Taxation

I have already shown that the individual profits of education can exceed the social benefits. Thus, a proportional income tax τ can reduce the individual skill premium towards the efficient level. With taxation a worker earns the net wage $\omega = (1-\tau)w$. The tax revenue is redistributed as lump-sum transfer which has no effect on the education decision or efficiency. I do not consider redistributive motives that could also justify a proportional tax. In presence of overeducation, a moderate increase in τ can reduce the returns to education. In contrast, if the taxes are too high, this may force workers to abstain from education even if a degree would be efficient. In presence of continuing skill biased technical change, a continuous adjustment τ is necessary to retain efficiency.
A government that wants to avoid the temporary overeducation of type-h workers has to set τ such that

$$[\theta_h s(1) - \theta_l s(0)] \leq c.$$

If $\Omega_h^e < c < \Omega_h^s$, τ needs to be *at least* such that education does not pay:

$$(1-\tau)[\theta_h s(1) - \theta_l s(0)] \leq c, \tag{18}$$

$$\tau \geq \frac{\theta_h s(1) - \theta_l s(0) - c}{\theta_h s(1) - \theta_l s(0)}. \tag{19}$$

This level of τ is sufficient to deter high ability workers. However, once $c < \Omega_h^e$, we *want* these workers to study, so

$$(1-\tau)[\theta_h s(1) - \theta_l s(n)] \geq c, \tag{20}$$

$$\tau \leq \frac{\theta_h s(1) - \theta_l s(0) - c}{\theta_h s(m) - \theta_l s(0)}. \tag{21}$$

If A raises further, taxes must be sufficiently high to deter low ability workers from studying as long as $c > \Omega_l^e$. In particular, it is necessary that (21) holds and that

$$(1-\tau)[\theta_h s(1) - \theta_l s(0)] \leq \lambda c \tag{22}$$

$$\tau \geq \frac{\theta_h s(1) - \theta_l s(0) - \lambda c}{\theta_h s(1) - \theta_l s(0)} \tag{23}$$

If $c \leq \Omega_l^e$, also workers with θ_l should study, thus

$$\tau \leq \frac{\theta_h s(1) - \theta_l s(0) - \lambda c}{\theta_h s(1) - \theta_l s(0)}. \tag{24}$$

Figure 4 illustrates the range for the optimal tax rate using the numerical example of section 4.

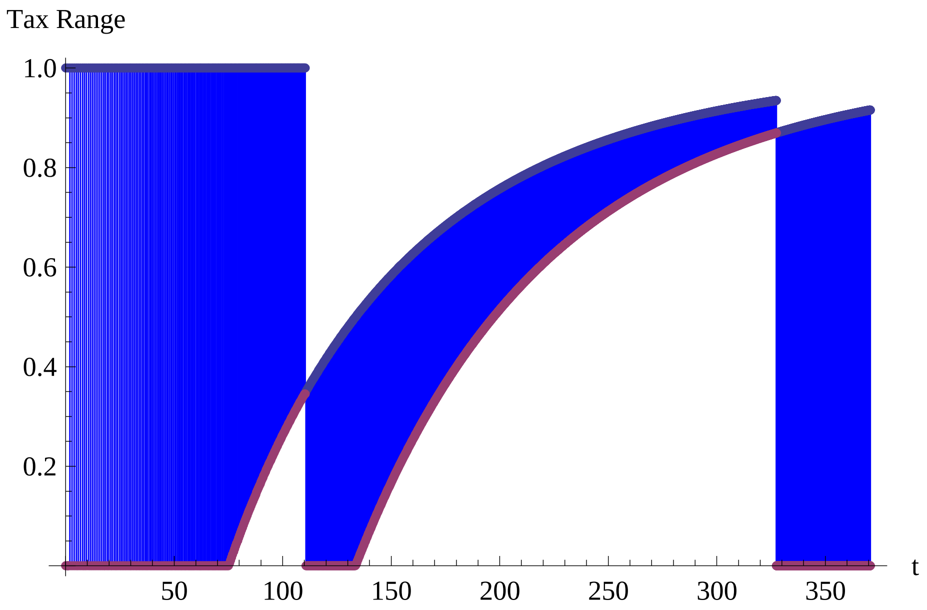

Figure 4: Tax range for efficient investment in human capital

6 Conclusions

This signaling model offers an explanation for the steep increase in the US wage inequality in the 1980s and the relatively constant inequality in the 1990s despite the continuing skill biased technological change. The model suggests that in the 1980s, when the productivity differential between highly talented and less able workers was quite moderate, it paid only for very able workers with low costs of studying to acquire a higher education. Firms expected that the average college graduate was highly productive, so these workers could fully benefit from continuing SBTC.

As SBTC continued, the productivity differential between workers with high and with low ability reached a threshold in which it paid also for less able workers to fight through college and to mimic to be specialists. The firms observed the increasing number of graduates, but they were not able to perfectly observe the ability of an individual worker. Thus, the wages of specialists were diluted by the competition by less able workers. Such a hybrid or pooling equilibrium reduces the effect of SBTC on skilled wages compared to a separating equilibrium.

The dynamic effect of SBTC on human capital gives rise to alternating periods of overeducation and efficient education. An adequate dynamically adjusted income tax can preclude these inefficiencies.

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