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Wage Inequality and Unemployment with Overeducation

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Wage inequality and unemployment with overeducation

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Abstract

A skill-biased change in technology can account at once for the changes observed in a number of important variables of the US labour market between 1970 and 1990. These include the increasing inequality in wages, both between and within education groups, and the increase in unemployment at all levels of education. In contrast, in previous literature this type of technology shock cannot account for all of these changes. The paper uses a matching model with a segmented labour market, an imperfect correlation between individual ability and education, and a fixed cost of setting up a job. The endogenous increase in overeducation is key to understand the response of unemployment to the technology shock.

Key words: unemployment, wage premium, overeducation, SBTC
JEL: E24, J31, J64

1 Introduction

In the U.S., between 1970 and 1990, unemployment rates for both high-school graduates and college graduates nearly doubled, the wage differential (or premium) between these two education groups widened considerably, and residual wage inequality within the two groups also rose. Table 1 reports figures on the

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first three variables for the male population in 1970 and 1990.[1] Juhn et al (1993) and Lemieux (2004), among others, have documented document the typical upward shifts of residual inequality within the high-school and college groups.[2] The period 1970-1990 is also one where there are clear indications of a rise in the fraction of college graduates that take non-graduate jobs, a phenomenon known as overeducation. Pryor and Schaffer (1997) and Wolff (2000) supply compelling evidence that since 1971 university graduates have increasingly been taking jobs in which the average educational level is much lower.[3]

Table 1. U.S. labour market 1970-1990

year	college unemployment rate	high-school unemployment rate	wage premium
1970	1.1	2.4	1.44
1990	2.1	5.3	1.58

A skill-biased change in technology (hereafter also a SBTC) is commonly regarded as the primary explanation for the widening dispersion of wages. This paper's central point is that the same SBTC which drives wage dispersion may also imply a surge in overeducation that helps explain much of the observed changes in unemployment. This contrasts favourably with existing studies where a SBTC cannot account simultaneously for a rise in educated unemployment, a widening in wage dispersion – both across and within education groups – and an upward shift in the degree of overeducation.

In order to articulate this point, the model in our previous work Cuadras-Morató and Mateos-Planas (2006) (henceforth CMMP) is adapted so that the analysis can account for the phenomenon of over-education. Like CMMP, this paper uses a search-matching model of a labour market that is segmented into two education levels. Segmentation means that both vacant firms and unemployed workers confine their search efforts to the particular segment they choose, not to both. Workers are differentiated by skill (or ability) and education, with these two attributes being only imperfectly correlated. Therefore,

[1] For unemployment, the figures are calculated from the Statistical Abstracts of the US, US Census Bureau (1995), Table 662. The unemployment rates refer to male civilian non-institutional population aged 25-64. The wage premium is the average wage of college white male workers over the average wage for high-school white male workers aged 18-64 as reported in Murphy and Welch (1992) for the years 1969 and 1989 (see also Katz and Murphy (1992) and Card and Di Nardo (2002)).

[2] The sustained increase in overall residual inequality during this period has been extensively documented and studied. See, for example, Krusell et al. (2000), Violante (2002), and Heathcote el al. (2004).

[3] However Acemoglu (1999), based on PSID survey responses, reports indications of a slight fall in overeducation between 1976 and 1985.

changes in workers' career (or segment) choices may have implications for equilibrium unemployment and wages across education groups. An educated worker has to decide which of the two segments to participate in depending on the employment and wage prospects associated with the two alternatives, whereas a non-educated can only participate in the non-educated segment. Firms decide which education segment to participate in, and which level of skills to hire taking into account the skill composition of the labour force in the different segments. Workers and firms interact in this economy in an otherwise standard framework with search and matching frictions to determine wages and vacancy/unemployment ratios in the two segments.

In contrast with CMMP, the present paper introduces a positive fixed start-up cost of creating a job. This proves to be a key feature for overeducation to arise as a result of the career decisions made by certain educated workers. An educated worker may turn to the non-educated segment and thus become overeducated when her chances of employment in the educated segment become slim. This can happen to educated yet low skilled individuals when, due to the existence of the fixed cost, educated firms refuse to hire them.

The specific objective of this paper is to use this model to study, both qualitatively and quantitatively, the ability of a skill-biased change in technology to account for the observed differences in wage inequality and unemployment conditions between 1970 and 1990. Moreover, it seeks an interpretation for the well known observed decline in the college premium during the early sub-period 1970-1980 – a time when college attainment in the labour force was growing very rapidly. The model is analysed to establish some of its basic properties and draw possible implications of a SBTC and changes in the composition of skills in the labour force for the observable variables. Numerical exercises are then conducted to study these effects quantitatively. The benchmark parameters are set to match some long-run observations for the US economy and the 1970 values of key endogenous variables. In the main exercise, the exogenous SBTC shock is measured to match the observed changes in the wage premium between 1970 and 1990. In another exercise, the SBTC shock is accompanied by a decline in the skill composition of the educated labour force. These two sets of shocks are then used to produce steady-state equilibrium outcomes for the entire range of labour market variables of interest which are to be compared, respectively, with the 1970-1990 and 1970-1980 facts reported above. In order to gain further quantitative insight, a shock to the general employment conditions in the form of a shift in matching technology will also be considered.

The findings are as follows. A SBTC may lead to a situation where firms looking for educated workers will not find it profitable to hire low-productivity individuals who will, consequently, turn to seek employment in the segment of firms that do not require qualified workers. This overeducation then causes higher unemployment within the educated group since the fraction of overeducated workers are subject to the tougher high-unemployment conditions of the non-educated segment. This can also be consistent with a higher unemployment rate for the non-educated workers and widening wage dispersion across and within education groups. The quantitative exercises demonstrate that the SBTC can account for most of the changes in the wage premium and the educated unemployment rate between 1970 and 1990, and most of the rise in the non-educated unemployment rate. Moreover, this is also qualitatively in accord with the observed upward shift in overeducation and residual inequality. As for the fall in the wage premium during the earlier subperiod 1970-1980, a SBTC still remains a very plausible explanation for the rising unemployment rates if accompanied by an empirically defensible temporary decline in the proportion of skilled workers within the educated group. The marked growth in the numbers of college graduates and the direct evidence on ability scores lend support to this hypothesis. This stands in contrast with the more common explanations based on a deterioration of the general employment conditions.

It is worth emphasising that these conclusions crucially rest on the specific assumptions made in the present paper that set it apart from the previous model in CMMP. That paper does not consider the existence of start-up costs and, as a consequence, overeducation is ruled out and an exogenous shock to the employment conditions, in addition to a SBTC, becomes indispensable to explain a rise in the unemployment rate of the educated labor force. The evidence on these shocks to employment conditions remains controversial though.[4] Instead, in the present paper a SBTC, a widely acknowledged phenomenon during the period, is sufficient to cause on its own most of the observed changes in all the variables because of the response of overeducation.[5]

Other papers have also studied the implications of a SBTC for dimensions of wage inequality and unemployment in a search-matching setup. This literature includes Mortensen and Pissarides (1999), Acemoglu (1999), Albrecht and Vroman (2002), Shi (2002), Dolado et al. (2003), Wong (2003), and Moore and Rajan (2005). The differences in results and approach between the present and these papers can be outlined as follows. Regarding the results, in the present paper a SBTC causes rises in unemployment rates and residual inequality within the two education groups, a higher wage premium, and a higher degree of overeducation. In these other papers, a SBTC fails in at least two

[4] Blanchard and Diamond (1989) and Bleakey and Furhrer (1997) discuss the empirical relevance of changes in the efficiency of the matching process.

[5] Also, CMMP endogenises the distribution of skill and education in the labour force through the individual choices of education. Although changes in education there play a central role in explaining the wage premium and the unemployment rates, they have counterfactual implications for a variable which will be of interest in the present paper, residual inequality.

of these dimensions. Mortensen and Pissarides (1999) cannot explain rising skilled unemployment and, by design, says nothing about overeducation or residual inequality within education groups. Acemoglu (1999) fails to explain rising residual inequality in any group and Albrecht and Vronan (2002) fails in the unskilled group. In Dolado et al. (2003), which introduces on-the-job search, the unemployment rate of the educated falls rather than rises. These three papers imply a reduction of overeducation (or mismatch) rather than an increase. In the present paper, the reduction in mismatch is associated with higher overeducation instead. In Shi (2002) residual inequality among the skilled remains constant at zero and the unemployment rate of the educated declines. In Wong (2003) residual inequality and the unemployment rate both decline. In Moore and Rajan (2005) wage inequality increases but unemployment falls for the skilled and, under some conditions, for the unskilled too. On the other hand, only Mortensen and Pissarides (1999), and Wong (2003) share with the present paper a quantitative approach to evaluating the implications of the theory. [6]

These contrasting results between the present and the other papers cited can be traced down to basic characteristics of the formal analysis. First, in the current paper the assumed imperfect correlation between education and skill has an important role. The previous papers treat education as equivalent to skill instead. Second, and related to the previous point, the present model assumes that the labour market is segmented in terms of jobs with different observable education requirements rather than skill requirements. Technically, there is a matching function for each segment. However firms in the two segments have the same production technology. The assumption in Mortensen and Pissarides (1999) is similar but, there, each different segment is perfectly associated with each of the (many) observable productivity-skill levels. In Acemoglu (1999) there is no segmentation in the sense of the present paper, so education is not used to sort applicants into job categories through differentiated matching processes. [7] This is also true of Albrecht and Vroman (2002), Dolado et al.(2003), and Wong (2003) where there are however two types of firms with different technologies of production. Two types of firms are also assumed in Shi (2002) but that is a model of directed search where the endogenous matching process leads to a segmentation similar to that in the present paper. Third, in

[6] In Acemoglu (1999), there are no initial differences in unemployment between education categories; in Albrecht and Vroman (2002) and Dolado et al. (2003) there is residual inequality only among the skilled; in Shi (2002) there is residual inequality only among the unskilled.

[7] Therefore, in the equilibria studied in the present paper all firms within any of the two segments will be of the same type. This rules out situations with two types of firms catering for workers with different skill level in the same segment, which is precisely the type of situation that corresponds to a *separating* equilibrium in Acemoglu (1999)'s model of a single-segment market. The present paper assumes instead two segments and only considers *pooling* equilibria within each segment.

the present paper a SBTC effects a shift in the segment choice by educated workers with different skill characteristics which brings about key changes in the skill composition of the labour supply in the different segments. The stories in Acemoglu (1999), Albrecht and Vroman (2002), Dolado et al.(2003), and Wong (2003) rest also on a shift in the pairing of workers' skills and firms' types but these cannot have such implications for the makeup of the labour supply.

The rest of the paper is organized as follows. Section 2 presents the model and basic behavior relations. Section 3 characterizes the equilibrium. Section 4 discusses qualitatively some key comparative statics. Section 5 presents the baseline calibration. Section 6 reports the results of the numerical analysis. Section 7 concludes the paper.

2 Model

There are two types of agents in the model, workers and firms. A worker's type is defined by two characteristics: skill (indexed by j) and education (indexed by i). A worker can be skilled ($j = s$) or non-skilled ($j = ns$), and educated ($i = e$) or non-educated ($i = ne$). Workers can be either working for firm or searching for a job. Firms can be either searching for a worker to fill a job vacancy or producing output with one worker. Workers and firms that are searching meet through a matching process. Firms observe the education status of a worker at any time but only observe her skill level after being matched. It is assumed that a posted vacancy must be directed to workers of a specific education group. More specifically, a firm targets either educated or non-educated workers to fill a vacancy, and its type is defined accordingly, educated or non-educated $i \in \{e, ne\}$. This implies that the labour market is segmented by education requirements, with a matching process taking place in each segment separately. A worker who does not hold proof of education is prevented from searching in the educated segment. The rest of this section describes the model and the decision problems faced by workers and firms. Attention is restricted to stationary situations.

2.1 Workers

Workers in the labour force are distributed over the four types according to a distribution whereby $\mu(j, i)$ denotes the fraction of workers with skill level $j \in \{s, ns\}$ and education $i \in \{e, ne\}$. Workers may leave the labour force with a constant probability ρ. When a worker leaves, another worker of exactly the same type replaces her. This distribution is exogenous. [8]

The timing of events for a worker is as follows. First, the worker enters the labour force and decides which segment (or career) of the market, $i \in \{e, ne\}$, to participate in. A non-educated worker can only search for jobs in the non-educated segment, while educated workers can search in either segment. Let $\phi_j \in \{0, 1\}$ represent the decision of an educated worker with skill j whether to participate (value 1) or not in the educated segment, so $1 - \phi_j$ is her decision to participate in the non-educated segment. The given distribution of the labour force over skill and education status and the career decisions will jointly determine the skill composition of the labour force that participates in each segment, $p_{j|i}$: the proportion of workers in segment $i \in \{e, ne\}$ with skill $j \in \{s, ns\}$. An explicit expression for the distribution of skills within each segment can be written as follows:

$$
\begin{aligned}
p_{s|e} &= \frac{\phi_s \mu(s,e)}{\phi_s \mu(s,e) + \phi_{ns}\mu(ns,e)} \\
p_{s|ne} &= \frac{\mu(s,ne) + (1-\phi_s)\mu(s,e)}{\mu(s,ne) + \mu(ns,ne) + (1-\phi_{ns})\mu(ns,e)}
\end{aligned}
\tag{1}
$$

Second, the worker starts searching for a job. Workers and firms are matched randomly. The probability that a worker searching in segment i makes contact with a suitable firm is ν_i. The value to a worker with skill j seeking employment in segment i is denoted by $U(j, i)$. In a steady-state, the Bellman values are not indexed by the worker's education type because the worker, even if educated, will never want to exercise the option to switch segment at a later date. Third, after contacting a firm, the skill of the worker j is revealed and the worker must agree with the firm on whether to create the job or continue searching. The decision of the firm about hiring the worker is denoted by the indicator $\pi_{j|i} \in \{0, 1\}$, with value 1 if the decision is positive. If the job is created, the wage to the worker is $w(j, i)$ and the value of the match is $W(j, i)$. The job is terminated exogeneously with a Poisson probability λ. If this happens, the agent becomes unemployed and searches for a new job. There is a flow value to the unemployed worker that depends on the wage:

$$b(w(j,i)) = b_0 + b_1 w(j,i) \tag{2}$$

where b_1 can be interpreted as the unemployment benefit replacement rate, and the fixed component b_0 may include the value of leisure.

The worker seeks to maximise the expected present value of utility. The instantaneous utility is given by the value of consumption and the future is

[8] In Cuadras-Morató and Mateos-Planas (2006) it is an endogenous variable.

discounted at the constant rate r. There is free borrowing and lending so in equilibrium the interest rate equals r and the worker maximizes the present value of wages plus unemployment compensation. The Bellman equation for $W(j,i)$ is

$$(r+\rho)W(j,i) = w(j,i) + \lambda(U(j,i) - W(j,i)). \tag{3}$$

The value of unemployment for a worker with skill j in segment i is

$$(r+\rho)U(j,i) = b(w(j,i)) + \nu_i \pi_{j|i} \max\{W(j,i) - U(j,i), 0\}. \tag{4}$$

As for career (or segment) choices, a non-educated worker can only search in segment ne. The career choice by an educated worker can be represented by

$$\phi_j = \begin{cases} 1 \; U(j,e) - U(j,ne) > 0 \\ 0 \text{ otherwise} \end{cases} \tag{5}$$

2.2 Firms

The timing of events is as follows. First, an inactive firm posts a job vacancy that specifies the education requirement on the worker sought (or market segment), i. The value of such a vacancy is $V(i)$. The firm contacts a suitable job seeker with probability ξ_i but cannot observe her skills at this stage. However the firm holds a rational belief about the probability that a matched worker in that segment has skill of type j. This coincides with the equilibrium fraction of workers with skill j within the pool of unemployed workers participating in the market segment i, $z_{j|i}$. The flow recruiting cost of posting a vacancy is c_R.

Second, upon contact, the firm observes the worker's skill, and the firm and the worker agree on whether to create the job. As before, $\pi_{j|i} \in \{0,1\}$ denotes the decision of the firm. When the job is created, the firm has to pay a fixed cost of c_k units associated with the training of the worker and/or administrative regulations.[9]

Third, the firm starts operating and earns a flow $y(j,i)$. The value of the job match for the firm is $J(j,i)$. When the job is terminated, the firm will seek to open a new vacancy type i of the highest value. The firm also discounts future values at the constant interest rate r. Formally, the Bellman equation for $J(j,i)$ is

$$rJ(j,i) = y(j,i) + (\lambda+\rho)\left[\max_{i' \in \{e,ne\}} V(i') - J(j,i)\right], \tag{6}$$

[9] Cuadras-Morató and Mateos-Planas (2006) assume $c_k = 0$.

and for the value of a vacancy $V(i)$,

$$rV(i) = -c_R + \xi_i \sum_{j=s,ns} z_{j|i}\pi_{j|i}[J(j,i) - V(i) - c_k] \tag{7a}$$

$$\pi_{j|i} = \begin{cases} 0 & J(j,i) - V(i) - c_k \leq 0 \\ 1 & J(j,i) - V(i) - c_k > 0 \end{cases} \tag{7b}$$

2.3 Technology

The total flow of output to a match satisfies

$$\eta_j = w(j,i) + y(j,i). \tag{8}$$

where η_j denotes the productivity of a worker with skill j. It is assumed that $\eta_s > \eta_{ns}$.

The matching technology is specified as a homogenous-of-degree-one function:

$$m(v,u) = m_0 v^{1-\theta} u^{\theta}, \qquad \theta \in [0,1],$$

This function gives the number of matches per period in segment i, $m_i = m(v_i, u_i)$, where v_i is the mass of vacant firms and u_i is the number of unemployed workers in this segment, and $m_0 > 0$ characterizes the efficiency of the matching process. Therefore the probabilities of contact for firms and workers are

$$\begin{aligned} \xi_i =& m_i/v_i = \xi(v_i/u_i) = m_0 \left(\frac{v_i}{u_i}\right)^{-\theta} \\ \nu_i =& m_i/u_i = \nu(v_i/u_i) = m_0 \left(\frac{v_i}{u_i}\right)^{1-\theta} \end{aligned} \tag{9}$$

so $\xi'(.) < 0$ and $\nu'(.) > 0$.

2.4 Bargaining, free-entry, and skills of the unemployed

The firm and the worker bargain at each instant over the surplus of the match to determine the wage. The solution to the corresponding generalized Nash bargaining problem is

$$w(j,i) = \arg\max\{\beta \log S_W(j,i) + (1-\beta)\log S_F(j,i)\},$$

where $S_W(j,i) \equiv W(j,i) - U(j,i)$ and $S_F(j,i) \equiv J(j,i) - V(i)$ represent the match surplus to the worker and the firm respectively, and β represents the workers' bargaining power. Using (2)-(4) and (6)-(7), the necessary first-order condition for this problem is:

$$\frac{1-\beta}{\beta(1-b_1)}(W(j,i)-U(j,i)) = J(j,i)-V(i) \tag{10}$$

Free-entry in vacancies leads to the exhaustion of pure rents from vacancy creation in both segments:

$$V(i) = 0 \tag{11}$$

The firms in a segment i take as given the skill composition of the unemployed workers from which matches are drawn, $z_{j|i}$. This depends of the skill-composition of the labour force in this segment, $p_{j|i}$, and the matching and hiring rates, ν_i and $\pi_{j|i}$. Supposing that workers accept the job offers made by firms, then in a steady-state the equalization of the flows in and out of employment will lead to the following expression:

$$z_{s|i} = 1 - z_{ns|i} = p_{s|i}\left(\frac{\nu_i\pi_{s|i}+\lambda+\rho}{\nu_i\pi_{ns|i}+\lambda+\rho}(1-p_{s|i})+p_{s|i}\right)^{-1} \tag{12}$$

3 Equilibrium

An equilibrium is a situation consistent with (1)-(11) above and, then, also (12) since workers always accept a job offer. [10] A more formal definition follows.

Definition. Consider as given λ, β, r, ρ, θ, $\mu(j,i)$, m_0, c_k, η_s, η_{ns}, α, b_0, b_1, and c_R. An equilibrium consists of values v_i/u_i, $w(j,i)$, $\pi_{j|i}$, and $p_{j|i}$, and ϕ_j, for $i = e, ne$ and $j = s, ns$ such that:

(i) Given $p_{j|i}$, the values v_i/u_i, $w(j,i)$ and $\pi_{j|i}$ satisfy (3),(4),(6),(7), (9)-(12).
(ii) Given v_i/u_i, $w(j,i)$, and $\pi_{j|i}$ for $i = e, ne$, the conditions in (5) determine ϕ_j for $j = s, ns$, with the value functions in (5) satisfying (3),(4),(6),(7), (8)-(12).
(iii) The values $p_{s|i}$ are determined from ϕ_j according to (1).
(iv) $p_{s|e} > p_{s|ne}$.

In point (i) the equilibrium can be analysed first for the case that the skill composition of the labour force in the two segments $p_{s|i}$'s are given. Conditions $(ii)-(iii)$ concern the determination of this composition $p_{s|i}$ through the career choices ϕ_j's. The last point (iv) is a restriction on the type of outcomes that are

[10] The decision of a worker whether to accept an offer in (4) is dominated by the hiring decision of the firm $\pi_{j|i}$ in (7b) since (10) must hold.

of interest, and will be discussed further in section 3.2 below. Before dealing with the interactions between career choices and the labour market outcomes, this section begins with the case that the career decisions are exogenous.

3.1 Exogenous career choices

This section studies first the equilibrium in each segment when the career choices ϕ_j's are exogenous (i.e., only point (i) of the definition needs to be satisfied), which implies that the distribution of skills (i.e., the $p_{j|i}$'s) is given too. Then an equilibrium determines the variables v_i/u_i (or, by (9), ν_i), $w(j,i)$, and $\pi_{j|i}$ for $i = e, ne$ and $j = s, ns$. They can be characterized by a couple of relationships.

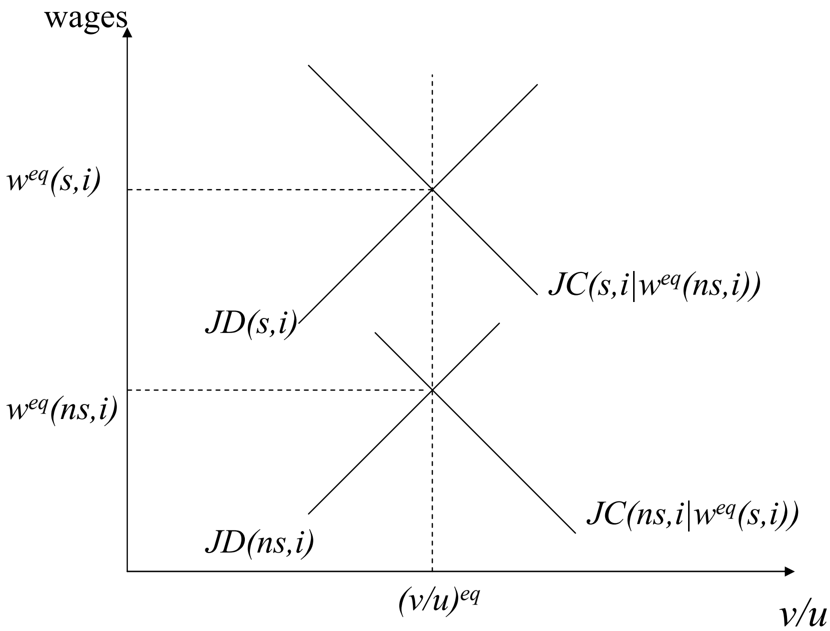

Figure 1. Equilibrium in segment i.

The first type of relation comes from the bargaining condition (10). This is the *job-destruction* curve which gives the wage as a function of the worker's skill, the segment's tightness and the firm's hiring decisions:

$$w(j,i) = \frac{(\eta_j - b_0 - b_1\eta_j)}{1-b_1}\frac{\beta\nu(v_i/u_i)\pi_{j|i} + \beta(r+\rho+\lambda)}{\beta\nu(v_i/u_i)\pi_{j|i} + (r+\rho+\lambda)} + \frac{b_0}{1-b_1} \qquad (13)$$

Expression (13) traces out a positive relation between the wage and the equilibrium market tightness – provided that the minimal condition $\eta_j(1-b_1)-b_0 > 0$ holds. The interpretation is that a higher probability of meeting a vacancy for the worker, ν_i, means that the outside option of a job is also higher. Hence the wage has to be also higher to keep the worker into the job. Since ν_i depends positively of market tightness, the positive relation between v_i/u_i and $w(j,i)$ follows. In Figure 1, the two upward-sloping curves denoted $JD(s,i)$ and $JD(ns,i)$ represent the two job-destruction relations described by (13), one for each skill level j.

The other type of relation comes from the free-entry condition (11):

$$\xi(v_i/u_i) \sum_{j=s,ns} z_{j|i}\pi_{j|i} \left[\frac{1}{r+\lambda+\rho} (\eta_j - w(j,i)) - c_k \right] - c_R = 0 \tag{14a}$$

$$\pi_{j|i} = \begin{cases} 0 \ \left[\frac{1}{r+\lambda+\rho} (\eta_j - w(j,i)) - c_k \right] < 0 \\ 1 \text{ otherwise} \end{cases} \tag{14b}$$

where the firm's net profit is in brackets and, using (12) with (9),

$$z_{s|i} = 1 - z_{ns|i} = p_{s|i} \left(\frac{\nu(v_i/u_i)\pi_{s|i} + \lambda + \rho}{\nu(v_i/u_i)\pi_{ns|i} + \lambda + \rho} (1 - p_{s|i}) + p_{s|i} \right)^{-1} \tag{14c}$$

This expression is associated with the idea of *job creation.* A higher probability of contacting a worker, ξ_i, increases the expected profits for the firm. Free-entry would drive the wages upwards so as to restore the zero value of creating vacancies. Since ξ_i depends negatively on market tightness, a negative relation between v_i/u_i and wages follows for each $j = s, ns$. In Figure 1, the two downward-sloping curves denoted JC are associated with the job-creation relation implied by (14), one for each skill level. More specifically, for a given tightness v_i/u_i, the corresponding point on $JC(s, i \mid w^{eq}(ns,i))$ represents the skilled wage that satisfies (14) for the given equilibrium non-skilled wage $w^{eq}(ns,i)$. Points on the other curve $JC(ns, i \mid w^{eq}(s,i))$ represent the non-skilled wage consistent with (14) given the equilibrium skilled wage $w^{eq}(s,i)$. Note that any of the two curves exists only as long as the firms in the segment are willing to hire the worker of the corresponding skill level j (i.e., $\pi_{j|i} = 1$) and that if instead $\pi_{j|i} = 0$ then $JC(j,i)$ cannot be drawn.

For each segment i, the equilibrium can then be expressed as a market tightness v_i/u_i and a pair of wages $w(s,i)$ and $w(ns,i)$ that satisfy (13) and (14). Graphically, in Figure 1 the equilibrium is characterized by the single market tightness and the two wages where the pairs of curves JC and JD associated with each skill level intersect, and the wages so determined match the equilibrium values underlying the two JC curves.[11]

[11] If for example the ns workers are not hired and $\pi_{ns|i} = 0$, then the equilibrium if fully characterized by the intersection between $JD(s,i)$ and $JC(s,i)$ where the latter does not depend on $w(ns,i)$. This notional wage $w(ns,i)$ is still given by the

This representation of the equilibrium as the solution to the system (13)-(14) will prove useful to articulate the discussion of comparative statics later on. However, in order to establish fundamental results on existence, multiplicity, and properties of the equilibria a more manageable version will prove useful. It can be derived by writing (13) as

$$\eta_j - w(j,i) = \frac{(r+\rho+\lambda)(1-\beta)[(1-b_1)\eta_j - b_0]}{(1-b_1)(r+\rho+\lambda+\beta\nu(v_i/u_i)\pi_{j|i})} \tag{15}$$

which can be used to replace the terms $\eta_j - w(j,i)$ in (14). This delivers a single equation in market tightness whose solution is an equilibrium. The equilibrium in segment i can then be expressed as a market tightness v_i/u_i that satisfies (14) with (15). It must therefore be consistent with the firm's hiring policy $\pi_{j|i}$ in (14b) which characterizes the choice of the firm whether to create the job when contacting an unemployed worker with skill j. There is the possibility that a match with a particular skill j is not profitable and the job is not created, but observe that (14a) requires that at least for one j the job is created. Changes in career decision enter this condition through changes in the composition of the labour force $p_{s|i}$ and thus the probabilities that, say, an unemployed worker is skilled in the educated segment, $z_{s|e}$, in (14c). Since the educated and the non-educated sectors are both operative, any firm must be willing to hire at least the skilled workers so that one can set $\pi_{s|e} = \pi_{s|ne} = 1$. In principle, the non-skilled workers may be hired in either sector, both sectors or none sector.

In order to make this characterization more precise Figure 2 is introduced. It represents the left-hand side of (14a) as a decreasing function of v_i/u_i, on account of (14b)-(14c) and (15). Thus an equilibrium must be unique. Also existence requires that the curve lies above the horizontal zero line for low values of the market tightness. Formally, given the limiting properties of the function $\xi(.)$, a necessary condition for existence is that firms be willing to hire at least skilled workers when tightness is very low.

The left-hand side of (14a) has a discontinuity at the value $(v_i/u_i)^*$ of market tightness where, according to (14b), $\pi_{ns|i}$ shifts from 1 to 0 or, in other words, the value at which it is no longer profitable for firms in segment i to hire non-skilled workers. At this point, the probability of meeting a skilled worker among the pool of unemployed, $z_{s|i}$ in (14c), drops because all the non-skilled workers in this segment become unemployed. An equilibrium may not exist due to this discontinuity. When there is a zero of the LHS of (14a) to the right of $(v_i/u_i)^*$, non-skilled workers are not hired, otherwise both skill types are hired. Figure 2 has been drawn for the latter case so $\pi_{ns|i} = 1$.[12]

point on $JD(ns,i)$.

[12] If all the labour force are non-skilled workers, there is no issue of discontinuity. For a very similar model, Cuadras-Morató and Mateos-Planas (2006) establishes

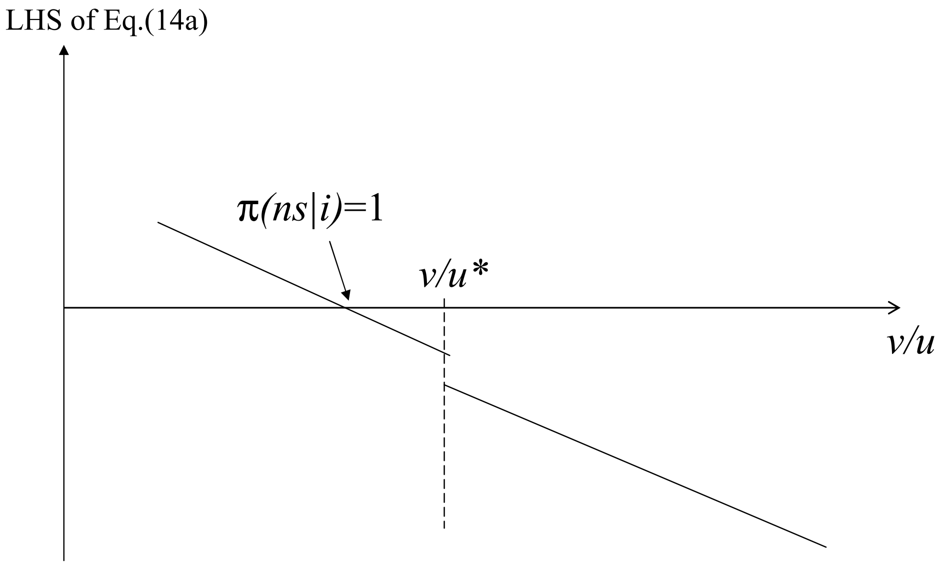

Figure 2. Equilibrium in segment i.

3.2 Endogenous career choices

The skill composition $p_{s|i}$ has been taken as given so far. In equilibrium, it must be consistent with points $(ii) - (iv)$ of the definition of equilibrium. That is to say, it must be true that there is a more skilled labour force in the educated segment $p_{s|e} > p_{s|ne}$, and that the $p_{j|i}$'s are determined by the career decisions of workers according to (1) and (5), with the equilibrium values of searching in alternative segments satisfying

$$(r+\rho)U(j,i) = b(w(j,i)) + \nu(v_i/u_i)\pi_{j|i}\frac{w(j,i) - b(w(j,i))}{r+\rho+\lambda+\nu(v_i/u_i)\pi_{j|i}}, \qquad (16)$$

where the equality follows from (3) and (4).

The last point iv implies that $\phi_s = 1$ and that the key interesting career decision is ϕ_{ns}. The analysis will be restricted to equilibrium situations where both the educated and the non-educated labour-market segments are operative, and where the proportion of skilled workers is higher among the labour force that participates in the educated segment (i.e., $p_{s|e} > p_{s|ne}$). The latter is intuitive and convenient since it restricts the type of career choices that may arise in equilibrium. In effect, the skilled workers that are educated must decide to participate in the educated segment, or $\phi_s = 1$. Otherwise, existence of an active educated segment would require the non-skilled educated workers to

this characterisation more formally.

be the only participants in the educated segment. But then non-skilled agents would be most numerous in the educated segment, which is inconsistent with the required condition on the $p_{j|i}$'s. That $\phi_s = 1$ will in turn imply, by (5) with (16) and (13), that in equilibrium market tightness is higher in the educated segment.

Proposition 1. *In an equilibrium workers who are educated and skilled must participate in the educated segment, or $\phi_s = 1$, and market tightness is higher in that segment, or $v_e/u_e > v_{ne}/u_{ne}$.*

Thus variation in labour-force participation (or career) will occur only through the choice by the educated non-skilled workers, ϕ_{ns}. An unsurprising yet important result is that educated non-skilled workers will turn to the non-educated segments when they see no chance of employment in the educated segment.[13] The reverse implication that educated individuals will leave the educated segment only if firms there do not hire them is also true. Proposition 2 states this more precisely.

Proposition 2. *Suppose that $\pi_{ns|ne} = 1$. Then $\pi_{ns|e} = 0$ if and only if $\phi_{ns} = 0$.*

Proof: If $\pi_{j|i} = 1$ then (7b) and (10) imply that $W(j,i) - U(j,i) > 0$. Using this in (3) and (4) shows that if $\pi_{j|i} = 1$ then

$$(r+\rho)U(j,i) = b(w(j,i)) + \frac{\nu_i \pi_{j|i}}{\nu_i \pi_{j|i} + \lambda + r + \rho}(w(j,i) - b(w(j,i))),$$

with $w(j,i) - b(w(j,i)) > 0$. On the other hand, if $\pi_{j|i} = 0$ then, by (4), $(r+\rho)U(j,i) = b(w(j,i))$.

First one has to prove that $\pi_{ns|ne} = 1$ and $\pi_{ns|e} = 0$ imply $\phi_{ns} = 0$. The result requires, from (5), $U(ns,e) < U(ns,ne)$. Given the preceding discussion, it suffices to prove that $w(ns,ne) > w(ns,e)$, which follows by using (13).

Second one has to prove the reverse that $\pi_{ns|ne} = 1$ and $\phi_{ns} = 0$ imply $\pi_{ns|e} = 0$. One can proceed by contradiction by assuming $\pi_{ns|e} = 1$. Use the discussion opening this proof to write the expressions for $U(ns,e)$ and $U(ns,ne)$. Using the Proposition 1 that $\nu_e > \nu_{ne}$ and, from (13), that $w(ns,e) > w(ne,ne)$, it follows that $U(ns,e) > U(ns,ne)$. From (5) this is a contradiction with the assumption that $\phi_{ns} = 0$. *Q.E.D.*

When, like under the conditions of Proposition 2, $\phi_{ns} = 0$ then there are educated workers that perform jobs that do not require a qualification. This is a form of the phenomenon known as overeducation.

[13] From (16) the sign of the difference between $U(ns,e) - U(ns,ne)$ in (5) depends on the sign of $w(ns,e) - w(ns,ne)$ which, by (13), is negative .

In general, one has to account for the possibility that two equilibria exist, one with $\phi_{ns} = 0$ and the other with $\phi_{ns} = 1$. In the case that $\phi_{ns} = 1$ all educated workers, including those unskilled, participate in the educated segment. Graphically, in Figure 2 the equilibrium tightness in the educated segment v_e/u_e is located to the left of the threshold $(v_e/u_e)^*$ and $\pi_{ns|e} = 1$. If there exists another equilibrium with $\phi_{ns} = 0$, it will have overeducation and a skill composition where, relative to the equilibrium with $\phi_{ns} = 1$, the skill of the labour force improves in the educated segment and worsens in the non-educated segment (see (1)). Graphically, in Figure 2 the equilibrium tightness in the educated segment v_e/u_e is located to the right of the threshold $(v_e/u_e)^*$. The large tightness in the educated segment confirms the firm's decision to turn down non-skilled workers, $\pi_{ns|e} = 0$ (see (14b) with (15)), and thus the career choice by non-skilled workers to leave the educated segment, $\phi_{ns} = 0$ (see Proposition 2).

4 Comparative statics

For the purpose of this paper it will be important to identify the theoretical effects of exogenous factors on the endogenous variables of the model. This section discusses the consequences of a skill biased change in technology and the possible ensuing shifts in the skill composition of the labour force. A skill-biased shock widens the productivity gap between skilled and unskilled workers, so it will be represented as a rise in the skilled productivity η_s and a reduction in non-skilled productivity η_{ns} of equal size.

It will be supposed that the economy is initially in a steady-state equilibrium where unskilled yet educated workers do in effect participate in the educated segment, or $\phi_{ns} = 1$, and consequently by Proposition 2 these workers can find employment in the educated segment, or $\pi_{ns|e} = 1$. In other words, there is no overeducation since all educated workers are employed in the educated segment. Graphically, the equilibrium wage structure $w(j, i)$ and market tightness v_i/u_i in each segment are determined as in Figures 1 and 2. As for the joint distribution of skills and education in the labor force $\mu(j, i)$, it will be assumed that the majority of educated agents are skilled and that the majority of non-educated workers are non-skilled. In the initial economy this means, by (1) and on account that $\phi_{ns} = 1$, that the composition of skills of the labor force in each segment satisfies that $p_{s|e} > 0.5$ and $p_{s|ne} < 0.5$.

The observable variables that are the object of this paper are the unemployment rates for educated and non-educated workers respectively, residual inequality within each education group, and the wage premium. These can be calculated by aggregating appropriately the equilibrium outcomes of the model. Note that in the initial economy, the fact that there is no overeducation means that outcomes within a specific education group coincide with the outcomes within the corresponding segment. For a start, it is supposed that the SBTC does not change this situation and thus ϕ_{ns} remains 1 after the shock. Then the possible response of the career choice ϕ_{ns} will be considered.

4.1 Skill-biased change without overeducation

Consider first the consequences of the SBTC in the educated segment. From (14) with (13) it is apparent that, given that $\pi_{s|e} = \pi_{ns|e} = 1$ in the initial equilibrium, the impact of the larger η_s and the lower η_{ns} on vacancy profitability depends on the skill composition of the pool of unemployed searchers in this segment $z_{s|e}$. Note that according to (14c), in the initial economy this coincides with the skill composition of the labor force in this segment $p_{s|e}$, which has been assumed to exceed 0.5. With these conditions, it is clear that the SBTC increases the value of vacancy creation in the educated segment as represented in the left-hand side of (14) with (15) when $i = e$. Therefore the market tightness v_e/u_e increases as the curve in Figure 2 shifts upwards. This will reduce the unemployment rate of educated workers. Wages as given in (13) increase for skilled jobs $w(s, e)$ but can go either way for unskilled jobs $w(ns, e)$. Graphically, the improvement in average productivity shifts upwards the job-creation curve JC for both skilled and non-skilled workers, but the skill-specific changes in productivity shift the job-destruction curves JD upwards for the skilled and downwards for the non skilled. As the gap between these two wage rates widens there is a rise in (residual) wage inequality within the group of educated workers.

Turning now to the non-educated segment, the lower η_{ns} implies a lower profitability of vacancy creation in this segment. This follows from the fact that, in contrast with the educated segment, this is a skill-scarce segment in that $z_{s|ne} = p_{s|ne} < 0.5$. Graphically, the curve in Figure 2 shifts downwards which causes tightness in this segment v_{ne}/u_{ne} to fall. The inevitable consequence is a rise in the unemployment rate of the non-educated workers. The wages in unskilled jobs $w(ns, ne)$ fall but the wage in skilled jobs $w(s, ne)$ can go either way. Graphically, the loss in average productivity shifts downward the job-creation curve JC for both skilled and non-skilled workers, but the skill-specific changes in productivity shift the job-destruction curves JD upwards for the skilled and downwards for the non skilled. Like in the educated segment, as the gap between these two wage rates widens, there is a rise in residual wage inequality within the group of non-educated workers too.

As for wage differences across groups, the direct impact of the SBTC on relative productivity will tend to increase the average wage of the skill-abundant educated group relative to the skill-scarce non-educated group. The wage premium must increase as a consequence. Note that this direct effect will be reinforced by the induced shifts in tightness and unemployment in the two segments.

In sum, a SBTC that increases wage inequality, both within and across groups, produces an increase in unemployment among non-educated workers but a fall in unemployment within the educated group. The latter is at odds with the generalized rise in unemployment in the US over the period 1970-1990.

4.2 Skill-biased change and overeducation

A skill-biased technical change can be large enough to change the initial policy of firms in the educated segment to hire non-skilled workers, $\pi_{ns|e} = 1$. The relative reduction in the productivity of non-skilled workers η_{ns} can, according to (14b) with (15), render them unprofitable in this segment and lead firms in this segment to refuse filling vacancies with such type of workers, or $\pi_{ns|e} = 0$. Proposition 2 then implies that unskilled workers will turn to the non-educated segment, or $\phi_{ns} = 0$, and overeducation arises. Note that, since it has to be assumed that $\eta_{ns} - b(\eta_{ns}) > 0$ for the non-educated firms to hire non-skilled workers, overeducation can only happen if the cost of creating a job c_k is positive.

In these circumstances, it is instructive to break down the consequences of a SBTC into a direct effect – similar to the one operating without overeducation and an unchanged $\pi_{ns|e} = 1$ – and an indirect effect which operates through the induced shifts in the skill composition of the labor force in the two segments.

Consider first the direct effect of the SBTC. In the educated segment, the curve in Figure 2, summarizing the equilibrium (14) and (15), shifts up far enough to determine and equilibrium to the right of the discontinuity which is the region where $\pi_{ns|e} = 0$. Note also that the threshold $(v_e/u_e)^*$ has shifted to the left. The rise in tightness also seen without overeducation follows. In terms of Figure 1, like in the case without overeducation, the JC curves move upwards, and the JD curves move up and down for the skilled and unskilled matches respectively, so a wider wage dispersion within the educated segment follows. Note, however, that since $\pi_{ns|e} = 0$ the JC curve for the non-skilled workers in Figure 1 ceases to exist.[14] In the non-educated segment, the direct effect of the SBTC follows along the same lines as in the case without overeducation. The fall in average productivity shifts downwards the curve in Figure 2 leading to a lower market tightness v_{ne}/u_{ne}.[15] The dispersion of wages paid in this

[14] Still the JD curve shifts downwards and determines the notional wage for the non-skilled workers $w(ns, e)$.

[15] This segment will always remain in the region to the left of the threshold

segment also widens following the shifts in the JC and JD curves in Figure 1 which parallel those in the case without overeducation.

Besides these direct effects, the rise in overeducation causes indirect effects operating through the associated shifts in the composition of the labour force in the two segments, $p_{s|e}$ and $p_{s|ne}$. In effect, that ϕ_{ns} goes from 1 to 0 means that the subset of educated workers who are non-skilled quit the educated segment and move into the non-educated segment. As it is clear from (1), the skill composition of labour then improves in the educated segment but worsens in the non-educated segment. The profitability of vacancy creation further increases in the educated segment and declines in the non-educated segment. This reinforces the shifts of the corresponding curves in Figure 2 and the job-creation curves JC in Figure 1 in the two segments and, therefore, the changes in the corresponding equilibrium market tightness and wages.

In sum, a SBTC brings about a widening gap between skilled and non-skilled wages in the two segments, a rise in tightness in the educated segment, and a fall in the non-educated segment. Following up the preceding discussion, this continues to be true if the SBTC also causes overeducation which, in fact, tends to reinforce those responses. As for aggregate measures of unemployment and earnings by education group, the emergence of overeducation might be more significant since it leads to the existence of a fraction of the educated labor force whose wages and unemployment will come to be determined within the high-unemployment (and low-wage) segment of non-educated jobs. It is thus that, when accompanied by overeducation, a SBTC might account for the rise in the educated unemployment rate characteristic of the US experience over the period 1970-1990. Remember from section 4.1 that, absent overeducation, a SBTC is bound to fail on that front.

5 Calibration

One model's period is assumed to correspond to one quarter. The parameters to be determined are: b_1, r, ρ, λ, θ, β, η_s, η_{ns}, b_0, c_R, m_0, c_k, and the skill distribution $\mu(j,i)$.[16] Six of these parameters can be set directly. The choice of b_1 is based on OECD (1997), λ on Stewart (2002), r on Cooley and Prescott (1995). A life-expectancy in the labor market of 45 years implies $\rho = 1/(45 \times 4)$. The matching elasticity θ is set following the estimate in Blanchard and Diamond (1990). The choice of m_0 is a normalization. The start-up cost c_k is chosen small enough so that in 1970 there is a regime with low overeducation or $\phi_{ns} = 1$ on account of the evidence in Pryor and Schaffer (1997) that 1970

$(v_{ne}/u_{ne})^*$ and thus $\pi_{ns|ne} = 1$.

[16] Much of this calibration will follow CMMP.

precedes the rise in overeducation.

To determine the remaining parameters, outcomes are restricted to be consistent with targets for the key endogenous variables corresponding to the year 1970. There are two blocks to this task. One block of the calibration procedure consists of matching the wage premium, the unemployment rates of educated and non-educated workers, and the value of the recruiting cost as a proportion of wage income by choice of the four parameters η_s, b_0, β, and c_R. It is assumed that $\eta_s + \eta_{ns} = 3$, and changes in η_s can be regarded as skill-biased changes in technology. The targets for the wage premium and unemployment are taken from the 1970 data of Table 1. The hiring cost is based on Hamermesh (1993).

Table 2. Calibration

parameter	value	target to match	source
b_1	0.2	UI replacement 20%	OECD (1997)
r	0.013	annual interest 5%	Cooley et al. (1995)
ρ	0.0055	working life 45 years	
λ	0.06	annual separation rate 25%	Stewart (2002)
θ	0.5	matching elast. 0.5	Blanchard et al. (1990)
m_0	1	normalize to unity	
c_k	0.05	low overeduc. $\phi_{ns} = 1$	Pryor et al. (1997)
$\mu(ns, e)$	0.085	college partic. 25%	US Census Bureau (1995)
$\mu(s, e)$	0.165	residual ineq. diff. 0.06	Gould (2002)
$\mu(s, ne)$	0.035		
$\mu(ns, ne)$	0.715	normalize mass 1	
$\eta_s = 3 - \eta_{ns}$	1.915	wage premium 1.44	Murphy et al. (1992)
b_0	0.770	unemp. educ. 1.1%	US Census Bureau (1995)
β	0.140	unemp. non-educ. 2.4%	US Census Bureau (1995)
c_R	0.10	recruiting costs 2%	Hamermesh (1993)

In the other block, the parameters $\mu(j, i)$'s are calibrated to match the targets of educational attainment and measures of inequality within defined occupational categories that can be associated with the two segments in the model. The education target can be written in terms of these parameters as $educ = \mu(s, e) + \mu(ns, e)$. Residual variances depend on the implied $p_{s|i}$'s which can be written $p_{s|e} = \mu(s, e)/educ$ and $p_{s|ne} = \mu(s, ne)/(1 - educ)$. These relations, along with the normalization $\sum_{i,j} \mu(j, i) = 1$, pin down the distribution parameters. The target for education is the 1970 figure for college participation of the male labor force aged 25 (see US Census Bureau, 1995, Table 629). Concerning inequality within job categories, Gould (2002, Fig. 1b) reports the variance of log-wage residuals within three different occupation groups.

The target to match will be the 0.06 differential residual variance of educated over non-educated jobs in 1970.[17] The choice made here implies that the skill composition of the two segments is given by $p_{s|e} = 0.660$ and $p_{s|ne} = 0.0467$. Table 2 displays the benchmark calibration and summarizes the procedure. All targets set out are matched exactly, with the educated and non-educated residual variances being 0.07 and 0.01.

6 Numerical exercises

This section studies the response of unemployment rates for educated and non-educated workers, residual inequality within each education group, and the wage premium to shifts in various exogenous factors within the model.[18] The factors considered will include a skill-biased change in technology, a shock to the level of employment frictions, and changes in the distribution of skills in the labor force. This section proceeds in several parts. In the first part the purpose is to explain the 1970-1990 changes in the U.S. labor market reported in Table 1. The primary explanatory factor considered will be a skill-biased change in technology, or SBTC. An additional shock to the level of employment frictions will also be considered. In the second, the quantitative model will be used to interpret the 1970-1980 developments where changes in the distribution of the labor force will play a role.

6.1 The role of a SBTC in the period 1970-1990

The skill-biased shock can be represented by a rise in the productivity of the skilled workers, η_s, and a corresponding decline in the productivity of the non-skilled workers, $\eta_{ns} = 3 - \eta_s$.[19] An employment shock can be represented by a reduction in m_0. This section reports the effect of this type of shock on the calibrated benchmark economy. The main results of the experiments conducted are contained in Table 3.[20] Each row shows first the value of the parameters η_s and m_0, and the endogenous career choice ϕ_{ns} which characterizes the

[17] In the model one can calculate the variance within a segment i as $(\log w(s,i) - \log w(ns,i))^2 p_{s|i}(1 - p_{s|i})$ where $p_{s|i}$ is the share of skilled in the segment.

[18] To trace the response of these variables it is necessary first to measure them more precisely in terms of the variables of the model. This is done in the Appendix.

[19] Equivalently, one might postulate a widening gap with positive growth in both productivities while the economy-wide parameters increase at an average rate that must exceed the rise in non-skilled productivity.

[20] Alternatively and to the same effect, this type of shock could be represented by an increase in the separation rate λ. See Cuadras-Morató and Mateos-Planas (2006) for a discussion of this point.

presence or absence of overeducation. The rest of entries on each row contain the key observable variables: the wage premium wp, the unemployment rate of the educated un_e, the unemployment rate of the non-educated un_{ne}, and the residual inequality for the educated, res_e, and the non-educated, res_{ne}. The first row shows the figures corresponding to the benchmark 1970 equilibrium. The second row reproduces the 1990 data on the observable variables in order to facilitate the comparison with the implications of the numerical experiments.

Table 3. Skill biased technical change and the 1970-1990 period

	parameters		overeducation	observable variables				
	η_s	m_0	ϕ_{ns}	wp	un_e	un_{ne}	res_e	res_{ne}
(1)	1.915	1.000	1	1.440	0.011	0.024	0.065	0.011
(2)				1.580	0.021	0.053		
(3)	1.980	1.000	1	1.533	0.011	0.032	0.089	0.015
(4)			0	1.545	0.017	0.033	0.092	0.014
(5)	1.990	1.000	0	1.561	0.018	0.035	0.096	0.015
(6)	2.010	1.000	0	1.594	0.020	0.041	0.104	0.015
(7)	2.010	0.800	0	1.591	0.024	0.051	0.101	0.014

The first experiment focuses on the skill-biased shock only. Rows 3 to 6 show the changes as η_s is increased. The third row corresponds to an equilibrium where, like in the initial benchmark, there is no overeducation. The wage premium, the measures of residual inequality, and the unemployment rate for the non-educated have increased. However, the unemployment rate of the educated labor force fails to increase. These conclusions conform the analysis presented above in section 4.1. Now for the same parameters, this economy has another equilibrium with overeducation and the fourth row shows the outcomes associated with it. The key feature of this equilibrium is the increase in the educated unemployment rate which follows from overeducation in the way discussed in section 4.2 above. The comparison of the third and fourth rows reveals that the increase in overeducation may on its own account for an increase in the educated unemployment rate as a consequence of a SBTC.

The fifth and sixth rows display the outcomes associated with larger SBTC's. The equilibrium is unique and features overeducation in that $\phi_{ns} = 0$. Specifically, the η_s in the sixth row has been chosen to nearly match the observed wage premium in 1990. We observe that, against the observed 1970-1990 changes, the SBTC so measured is able to produce nearly all of the rise in the educated unemployment rate and about sixty per cent of the rise in the non-educated unemployment rate, as well as a sizeable upward shifts in residual inequality within the two education groups. Thus the theory advanced early that a SBTC can account for the 1970-1990 changes in all the variables also fares well under the rigour of a quantitative exercise.

Although the SBTC accounts for much of the observed changes over the period 1970-1990, it still leaves unexplained a sizeable portion of the rise in the non-educated unemployment rate. This suggests some additional exogenous factor must have been at work. For example, one could think of an increase in labour market frictions that can be characterized by a lower efficiency of the matching process. The seventh row of Table 3 considers a reduction of the matching parameter m_0 alongside the SBTC characterized by an increase in $\eta_s - \eta_{ns}$. The fall in m_0 is tuned to nearly match the rise in non-educated unemployment. Although now the educated unemployment rate exceeds the 1990 observation, the combined effect of a SBTC and a mismatch shock provides a fairly complete account of the 1970-1990 facts.

6.2 The 1970-1980 period and the skill distribution

The wage premium declined markedly between 1970 and 1980 – from the initial 1.44 in Table 1 down to 1.37 – before launching on the subsequent sharper increases. How can this model reconcile this observation with the presence of SBTC driving up unemployment rates? It will be shown that a shift in the distribution of skills could account for this early decline. More specifically, the substantial increase in college participation or the entry of the baby boom generation into the labor force might have led to a deterioration of the average quality of the college workers, $\mu(s,e)$ up to, roughly, 1980. The evidence of declining GRE scores clearly supports this view. Figure 3 shows that the growth in college participation was particularly rapid in the period to the early 80's. Figure 3 also displays average GRE scores of verbal and numerical competence for college graduates, and shows a clear decline during the 70's. This trend is reversed past 1980 as, it seems plausible to conjecture, the education system adjusts to bring the skill composition $\mu(s,e)$ close to its initial 'natural' level by 1990.

This section explores the implications of these developments within the model. Table 4 shows the results of some calculations. Each row corresponds to a specific setting for the exogenous parameters associated with the SBTC, η_s, and the skills distribution, $\mu(s,e)$. In this experiments, a change in $\mu(s,e)$ is always accompanied by an adjustment of $\mu(ns,e)$ so that $\mu(s,e) + \mu(ns,e)$ remains constant. The first row of Table 4 reproduces the calibrated 1970 benchmark. The other rows from 2 to 6 demonstrate that, when accompanied with a lower $\mu(s,e)$, the SBTC can produce general rises in the two unemployment rates, and the two measures of residual inequality, at the same time as the wage premium declines. The SBTC still must be large enough to produce a switch in career choice ϕ_{ns} towards overeducation which accounts for most of the increase in the educated unemployment rate. Specifically, the fifth and sixth rows in Table 4 report outcomes which nearly match the observed 1.37 wage premium in 1980.

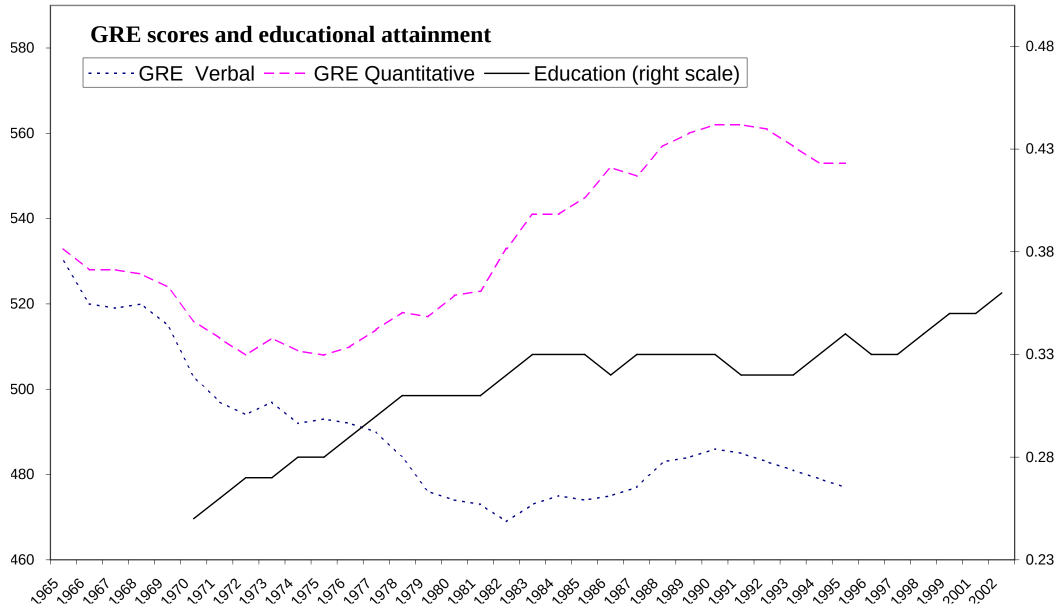

Figure 3. Educational attainment 1970-2002 as the percentage of male civilian force 25 to 64 years of age with a high school diploma who are college graduates. Source: *Women in the Labor Force: A Databook*, US Bureau of Labor Statistics, 2004. Graduate Record Examination (GRE) average scores of quantitative and verbal competence, 1965-1995. Source: *Digest of education statistics, tables and figures 1996*, National Center for Education Statistics (http://nces.ed.gov).

Table 4. SBTC, skills distribution, and the 1970-1980 period

	parameters		overeducation	observable variables				
	η_s	$\mu(s,e)$	ϕ_{ns}	wp	un_e	un_{ne}	res_e	res_{ne}
(1)	1.915	0.165	1	1.440	0.011	0.024	0.065	0.011
(2)	1.990	0.130	0	1.436	0.022	0.036	0.107	0.015
(3)	1.990	0.120	0	1.401	0.023	0.036	0.108	0.015
(4)	2.000	0.120	0	1.413	0.024	0.038	0.112	0.015
(5)	1.990	0.110	0	1.365	0.024	0.036	0.106	0.015
(6)	2.000	0.110	0	1.376	0.025	0.038	0.111	0.015

Table 5 reports experiments where, in addition to the SBTC and the change in the distribution of skills, there is a fall in the efficiency of matching. The first row corresponds again to the calibrated benchmark. The other entries consider combinations of η_s, $\mu(s,e)$ and m_0 that approximately match the 1980 wage premium of 1.37. The second row shows that without SBTC, a lower matching efficiency and skill of the educated cannot effect the increase in residual inequality among the non-educated, and overeducation cannot arise. The other variables move in the right direction although by substantially smaller amounts than in the case with SBTC and without the mismatch shock seen above in rows 5 and 6 of Table 4. It is only when a SBTC is added that there is a rise in residual inequality for the non-educated and, overall, changes are quantitatively more in line with observations. This is particularly true when, as it is the case in the third row, the SBTC is not big enough to cause overeducation. If there is overeducation instead the model implies too big an increase in the educated unemployment rate.

Table 5. SBTC, skills, and mismatch over 1970-1980

	parameters			overeduc	observable variables				
	η_s	$\mu(s,e)$	m_0	ϕ_{ns}	wp	un_e	un_{ne}	res_e	res_{ne}
(1)	1.915	0.165	1.00	1	1.440	0.011	0.024	0.065	0.011
(2)	1.915	0.140	0.80	1	1.364	0.015	0.031	0.069	0.011
(3)	1.980	0.120	0.80	1	1.370	0.016	0.040	0.094	0.014
(4)	1.990	0.110	0.80	1	1.344	0.017	0.042	0.096	0.014
(5)				0	1.364	0.030	0.045	0.105	0.014
(6)	2.000	0.110	0.80	1	1.353	0.017	0.045	0.101	0.014
(7)				0	1.375	0.032	0.048	0.109	0.014

In sum, a deterioration of the skills in the educated labor force is necessary to account for the 1970-1980 drop in the wage premium. A SBTC is also needed to account for residual inequality in this period. If the SBTC causes overeducation, then the addition of an extra shock in the form of a reduction in matching efficiency overestimates the rise in educated unemployment. With a large enough decline in matching efficiency, the model delivers unemployment outcomes comparable with the data for 1970-1980 only if the SBTC does not cause overeducation to rise. Since the direct evidence of overeducation is quite compelling, this analysis suggests that the SBTC can account for most of the changes in unemployment over the 1970-1980 subperiod.

7 Conclusion

This paper extends the standard search-matching model by introducing the possibility of overeducation in a segmented labor market where education and skill are not equivalent attributes of a worker. Equilibrium properties of the model are characterized. The model is used to study the response of unemployment and wage inequality to a skill-biased change.

The SBTC leads to increases in the wage premium, in residual inequality, and in the unemployment rates of both educated and non-educated workers. The endogenous increase in overeducation plays an essential part as it explains the consequences of the shock for the unemployment rate of educated workers. With overeducation, there are educated workers participating in the high-unemployment segment of jobs that do not require a degree. Overeducation occurs among the educated workers who have a low ability since, in the presence of a positive startup cost, the SBTC renders those workers unprofitable to firms in the educated segment. A calibrated setting is used to study quantitatively a skill-biased change in technology as the cause of the changes in education-specific unemployment rates and the wage premium in the U.S. economy between 1970 and 1990. This shock alone can account for most of the observed changes in these three variables, while being also consistent with the evidence of a wider residual dispersion in wages and a higher degree of overeducation. On the other hand, a temporary drop in the average skill quality within the educated group can reconcile the SBTC with the falling wage premium and soaring unemployment rates in the initial period 1970-1980, without need of invoking other explanations such as a decline in the efficiency of matching. This change in the skill composition can be motivated by the rapid growth in the numbers of college graduates and supported by some direct evidence from performance scores.

This paper has limitations which hint at interesting extensions. Changes in the distribution of skills and education status in the labor force have been treated as exogenous, but education choices could be made endogenous. The model cannot match observed levels of residual inequality and the implications on this dimension can only be assessed qualitatively. The analysis centers around steady-state outcomes which may have limitations, specially in reference to the subperiod 1970-1980.

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APPENDIX. Measurement of observable variables

The unemployment rate for the educated workers un_e averages the unemployment probabilities in the two segments where they can participate. In a steady-state it reads:

$$un_e = \frac{\lambda+\rho}{\lambda+\rho+\pi_{s|e}\nu(v_e/u_e)}\frac{\mu(s,e)}{\mu(s,e)+\mu(ns,e)} + \frac{\lambda+\rho}{\lambda+\rho+[\phi_{ns}\pi_{s|e}\nu(v_e/u_e)+(1-\phi_{ns})\pi_{ns|e}\nu(v_{ne}/u_{ne})]}\frac{\mu(ns,e)}{\mu(s,e)+\mu(ns,e)}$$

If all the educated workers participate in the educated segment then $\phi_{ns} = 1$ and their unemployment rate is fully determined by the tightness in that segment. Otherwise, $\phi_{ns} = 0$ and the tightness in the non-educated segment and the relative number of non-skilled educated workers who search in the non-educated segment will also matter. Note that since, by Proposition 2, tightness is lower in the non-educated segment, this form of over-education will tend to increase the overall unemployment rate of the educated labor force.

As for the non-educated workers, only the non-educated segment is available and the corresponding unemployment rate can be written as

$$un_{ne} = \frac{\lambda+\rho}{\lambda+\rho+\pi_{s|ne}\nu(v_{ne}/u_{ne})}\frac{\mu(s,ne)}{\mu(s,ne)+\mu(ns,ne)} + \frac{\lambda+\rho}{\lambda+\rho+\pi_{ns|ne}\nu(v_{ne}/u_{ne})}\frac{\mu(ns,ne)}{\mu(s,ne)+\mu(ns,ne)}$$

In the case we will always consider that $\pi_{s|ne} = \pi_{ns|ne} = 1$, the non-educated unemployment rate is fully determined by market tightness in the non-educated segment v_{ne}/u_{ne}.

Turning now to wages, the proportion of skilled among the educated employed workers is:

$$s_e = \mu(s,e)\left(1-\frac{\lambda+\rho}{\nu_e+\lambda+\rho}\right)\left[\mu(s,e)\left(1-\frac{\lambda+\rho}{\nu_e+\lambda+\rho}\right)+\mu(ns,e)\left(1-\frac{\lambda+\rho}{\phi_{ns}\nu_e+(1-\phi_{ns})\nu_e+\lambda+\rho}\right)\right]^{-1}$$

the proportion of skilled among the educated employed workers is $s_{ne} = \mu(s,ne)\left[\mu(s,ne)+\mu(ns,ne)\right]^{-1}$. Denote by $\tilde{w}(j,i)$ the wage earnt by a worker of skill j and education i. Naturally, $\tilde{w}(j,i) = w(j,i)$ except for $\tilde{w}(ns,e) = \phi_{ns}w(ns,e)+(1-\phi_{ns})w(ns,ne)$. The residual variances are $res_i = (\log\tilde{w}(s,i) - \log\tilde{w}(ns,i))^2 s_e(1-s_e)$ for $i = e, ne$. The average wage of each education group i are similarly calculated using s_i to weight the wages $\tilde{w}(j,i)$.