The Rising Skill Premium, Technological Change and Appropriability*

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Version 1.2

Abstract

In the US the skill premium and the non-production/production wage differential increased strongly from the late 1970s onwards. Skill-biased technological change, trade with unskilled-abundant countries and changes in the (domestic) supply of skilled workers have been proposed as explanatory factors. By the method of eliminating the impossible, skill-biased technological change is argued to be the dominant explanation. This paper shows that the dismissal of the increased supply of skill - which is argued to be countervailing rising skill premiums - is premature. In a simple model, well embedded in the literature on R&D, knowledge accumulation and (semi-)endogenous growth, it is shown that the demand curve for skilled labour might well be upward sloping. Our key assumption is that skilled labour is employed in non-production activities that both generate and use knowledge inputs. It is shown that the tension between non-rivalness and appropriability of R&D output is crucial for the sign of the slope of the skill-demand curve. A necessary condition for an upward sloping demand curve is the ability of firms to appropriate the intertemporal returns from non-production activities.

Keywords: wage inequality, growth, technological change, appropriability

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* The authors acknowledge Patrick Francois for stimulating discussions and comments. Comments on an earlier version by Theo van de Klundert are greatfully acknowledged.

1. Introduction

Wage inequality has increased since the early eighties in the US (see Table 1). This is a well documented but badly understood phenomenon. Three angles have been taken to analyse inequality; a change in educational attainment, a change in the bias in technological change and globalization or increased trade with low-wage countries. Among the competing explanations, a change in educational attainment was the first to be disqualified, as an increased average level of educational attainment is unlikely to explain an increased skill premium.[2] The competition between the two remaining explanations, biased technological change and trade, is still continuing.

Table 1 Non-production wage-bill and employment share, relative wage and R&D intensity in the US 1973-1989.[a]

	1973	1977	1981	1989
Non-production wage-bill share	.337	.351	.397	.414
Non-production employment share	.246	.261	.285	.303
Non-production/production wage differential	1.55	1.53	1.53	1.62
Supply of high education[bc]	10.8		16.6	21.5
R&D intensity manufacturing	.063	.062	.077	.087

[a]Source: Machin and Van Reenen (1998).
[b]Source: OECD Employment Outlook (1993).
[c]Share of college educated, for 1970, 1980 and 1990.

This paper reestablishes the potential importance of changes in educational attainment as an explanation for wage inequality. It is shown that in a simple model of endogenous technological progress with production and non-production jobs, increased educational attainment may raise demand for skilled workers. Hence, the demand curve for skilled workers can be upward sloping.

[2] Increased educational attainment implies a downward pressure on the relative wage of skilled workers. If, however, quality of high schools decreased (and hence the quality of unskilled workers decreases) this might offset the downward pressure.

Our key assumption is that skilled workers perform tasks that are fundamentally different from those of unskilled workers. We follow Reich's (1991) distinction between *routine production workers* and *symbolic analysts*. While unskilled routine workers contribute directly to (current) production, skilled workers are employed as non-production workers. The latter contribute to the continuous process of organizational change and improvements within a firm that affects the future productivity of the firm. In this process they build on and further expand the knowledge that is already accumulated within the firm. They thus act as "symbolic analysts", both using and producing new knowledge. For more on the type of work that is called unskilled, see the discussion on *routine production workers* by Reich (1991), for more on the skilled workers see his description of *symbolic analysts*.[3]

If the supply of skilled workers rises, the direct effect is a decrease in their wage in order to induce firms to absorb the increased supply and expand non-production jobs. This is the conventional effect. However, if firms employ more skilled non-production workers, the demand for knowledge inputs in non-production rises. To generate these inputs, skilled workers themselves should be employed, so demand for skilled labour increases. This second effect counteracts the conventional effect. Note that it is basically an induced *investment* effect: the expansion of non-production jobs triggers investment in organisational knowledge capital. If suffiently large, the investment effect may offset the conventional effect. Investment incentives are significant if the cost of capital does not increase too quickly in response to increased investment and if the returns to investment can be sufficiently appropriated. Indeed we find that under these circumstances, the firm is willing to attract skilled labour at a higher wage if educational attainment raises, that is, the demand curve for skilled labour slopes upward.

Our model replicates the main stylized facts that guide the wage-inequality debate. First, the majority of US industries have, despite the increases in the relative cost of skilled workers, increased the ratio of skilled to unskilled labour (Bound and Johnson, 1992, Berman, Bound and Griliches, 1994, Katz and Murphy, 1992). Table 1 shows that: the increased wage-bill share of non-production workers is due to both an increase in the non-production employment share as well as the non-production production wage ratio. Second, our model replicates the finding that skill upgrading is positively correlated with R&D intensity changes (Machin and Van Reenen, 1988). As a third stylized fact, it is

[3]The *in person service* type is ignored in the present analysis.

worth stressing that within industry increases in the ratio of skilled to unskilled workers overwhelm the between industry shifts (Bound and Johnson, 1992, Berman, Bound and Griliches, 1994, Katz and Murphy, 1992). Although intersectoral reallocations can be included in our model, we do not want to focus on this aspect.

This paper relates to the literature that analyses the interaction between technology, wage inequality and the endowment of skills, including Acemoglu (1998) and Galor and Moav (1998). Acemoglu (1998) is closely related to our approach in the sense that increases in the endowment of skills are causal in the increase in inequality. In Acemoglu, similar to this paper, the upward slope of the long-run demand curve for skill is driven by induced investment. The mechanism and assumptions driving the upward slope are, however, markedly different. First, Acemoglu, who threats skilled and unskilled workers as symmetric factors of production, ignores the different nature of production versus non-production work, a distinction we acknowledge explictly. Second, Acemoglu assumes that firms entering the reseach sector can choose between two distinct technological trajectories, that either improve productivity of skilled or of unskilled workers. We do not make an assumption about the existence of different technological trajectories but focus on the cumulative nature of the accumulation process of knowledge and organisational capital. Finally, we argue that decreasing returns in the knowledge accumulation process will *ultimately* reverse the prediction that a skill supply shock will increase wage inequality. Galor and Moav (1998), similarly, study the observations discussed earlier but emphasize the endowment of ability and within (skill) group inequality.

The emphasis in this paper on the investment character of skilled work relates the paper to the literature showing that skilled labour has a comparative advantage in implementing technology and R&D (Bartel and Lichtenberg, 1987).

Finally, this paper uses building blocks from the literature on endogenous growth like, for example, the intentional accumulation of knowledge by profit-maximising firms. Opposite to most benchmark growth models (e.g. Grossman and Helpman, 1991, and Romer, 1990), however, we assume that innovation mainly takes place within firms and that firms rely more on inhouse R&D and firm specific knowledge rather than on a pool of knowledge that is fully public (cf. Peretto, 1999 and Smulders and Van de Klundert, 1995). That spillovers are simply not complete and instanteneous is a fact well documented (see Jaffe, Trajtenberg, Henderson, 1993). We extend the theory of growth based on firm-specific knowledge by broadening the concept of technological change to organisation change (management etc).

The plan of the paper is as follows. Section 2.1 provides an overview of the model which is presented in greater detail in Section 2.2. Section 2.3 spells out the different effects that drive the skill premium. In the remainder of Section 2 the general equilibrium impacts of a supply shock to the skill endowment are analysed. Section 3 checks the robustness of our main results to a differentiation of non-production work in activities with an investment character and activities more closely related to production. Section 4 concludes.

2. A general equilibrium model of non-production jobs

2.1 Overview of the model

There is a continuum of firms, each supplying a unique product variant under monopolistic competition. For notational convenience we normalize the number of firms to unity. Firms hire two types of labour, labelled skilled (*H*) and and unskilled (*L*). The supply of both types of labour is exogenously given.

As explained in the Introduction, we interpret skilled workers as non-production workers to be contrasted to production workers which are suposed to be less skilled (note that most empirical research explicitly takes this interpretation). Indeed, education and training results in two types of skills. The more elementary skills consist of basic insights and capabilities to undertake given activities at a certain accuracy. Beyond this type of skills, there is more sophisticated skills and underlying knowledge to analyse existing activities and to generate new knowledge. Those who obtained the first type of education are called unskilled workers, those who also obtained the second type are called skilled workers. We may think of skilled workers as marketing managers, organisation experts, financial planners, research lab workers etc.

Firms maximize profits and consumers maximize utility. Consumers have Dixit-Stiglitz preference over a variety of goods. We consider a closed economy without uncertainty and perfect foresight in which all markets clear.

2.2 Technology and firm behaviour

Each firm produces according to the following production function:

$$x_i = h_i^{\beta} L_i^{\delta} \equiv F(h_i, L_i) \tag{1}$$

Final output is denoted *x*, *L* are unskilled workers[4] whose effectiveness or productivity depend on knowledge or (organisational) quality (*h*) created by skilled workers. Skilled workers (*H*) gradually improve the organisation, production technology or for example the

[4]Note that we assume decreasing returns to unskilled labour $0<\delta<1$. The underlying assumption is that the firm also employs a fixed factor whose size is normalized to one.

perceived quality by means of marketing. The one-dimensional variable *h* captures all these different aspects. The stylized representation of the accumulation process for ideas is as follows:

$$\dot{h}_i = \xi h_i^{\alpha} h_a^{\gamma} H_i^{\lambda} \equiv G(h_i, h_a, H_i), \qquad \alpha, \gamma, \lambda \in [0,1) \tag{2}$$

The (non-production) work of skilled workers improves the production environment for the unskilled workers.[5] They use two types of knowledge inputs. First, skilled workers analyse, exploit and expand the stock of accumulated firm-specific experience and organisational knowledge capital (h_i).[6] Second, skilled workers benefit from knowledge developed in other firms, as captured by the average knowledge level h_a in other firms. This second knowledge input is beyond control of the individual firm and gives rise to the intertemporal knowledge spillover externality that is familiar from R&D-based endogenous growth models. However, firms internalize the intertemporal spillover effect from own knowledge generation to their own non-production activities: they take into account that accumulation of specific knowledge not only affects production but also provides inputs for future research. Firms do not internalise the intertemporal spillovers to other firms because they cannot appropriate the associated returns. We assume that there are non-increasing returns to scale with respect to both types of knowledge taken together. That is, we either assume constant returns to scale ($\alpha+\gamma=1$), which implies endogenous growth (cf. Romer 1990), or diminishing returns to scale ($\alpha+\gamma<1$), which implies semi-endogenous growth (cf. Jones 1995).

Keely and Quah (1998) argue that a review of the empirical literature on R&D, technology and growth learns that: (1) inputs in the knowledge production function are strongly related to knowledge ouput and (2) output of knowledge production is inaccurately proxied by patents, as "Most knowledge accumulation does *not* occur from private firms' R&D producing *patentable* knowledge."[7] This latter observation motivates our choice for the perspective on knowledge as a firm-specific asset. A final observation is

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[5] There are decreasing returns with respect to skilled labour inputs. This captures the "stepping on toes effect", indicating congestion and duplication in research (see Jones, 1995, for an extensive discussion).

[6] For an extensive discussion on the firm specific nature of knowledge see Smulders and Van de Klundert (1995) and Peretto (1999). For an explicitly treatment of the tacitness of knowledge see Dosi (1988).

[7]See page 3, second italics added.

that spillovers do occur but do not happen automatically or completely. Hence, we do not assume *perfect* nor automatic knowledge spillovers, as is clear from the distinction between h_a and h_i in our specification.

Novel is the interpretation here that the regularities related to spillovers and knowledge accumulation -- familiar to the R&D based endogenous growth literature -- are extended to all non-production activities. To see the analogy between R&D and non-production work think of a new way of organising a firm. The implementation and development of new organisational schemes often takes years and builds on past experience. From the organisational scheme that a specific firm works out some more general principles can be useful for other firms, too. If this information is written down or disseminates in some way other firms might benefit too (h_a). However, a next firm reorganising might use this information but still needs to go through the process of convincing, motivating and adapting to specific "own" circumstances[8] (that is increasing the firms specific knowledge stock, h_i).

Demand for unskilled and skilled workers is determined by the firms' production and non-production decisions, given that firms perceive a downward sloping demand curve for final output.

Skilled workers' output is not sold on the market directly.[9] By hiring skilled workers, the firm can invest in firm-specific knowledge. The wage the firm is willing to pay for skilled labour thus depends on the return to investment in firm-specific knowledge. The firm invests up to the point that the marginal return to investment in firm-specific knowledge equals the cost of capital. This no-arbitrage condition can be written as:[10]

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[8]Jovanovics (1995) argues that adjustment and implementation costs of ideas dominates the non-rivalness of knowledge.

[9]Think of output of the marketing manager, the human resource manager, the product designers and the organisational experts.

[10]The following three equations can be straightforwardly derived from the firms dynamic optimization problem. Firms maximize profits, discounted by interest rate r, subject to (1), (2) and the downward sloping demand curve for its output. Suppressing the firm index i, we may write the Hamiltonian as $p(F(h,L))\cdot F(h,L) - w_L L - w_H H + qG(h,h_a,H)$, where $F()$ is the production function in (1) and $G()$ is the accumulation function in (2).

$$\frac{p\left(1-\frac{1}{\varepsilon}\right)\frac{\partial x}{\partial h} + q\frac{\partial \dot{h}}{\partial h} + \dot{q}}{q} = r \tag{3}$$

where ε is the elasticity of demand, r is the cost of capital (nominal interest rate) and q is the shadow value of firm-specific knowledge, or in other words the firms internal accounting price for non-production workers' output. The left-hand side of the equation represents the marginal return from non-production workers activities. The first term represents the value of their contribution to improving production efficiency, the second term represents the value of their contribution to providing knowledge inputs for the process of investment in firm-specific knowledge, and the final term captures a capital gain (capturing the fact that if the price to knowledge increases over time, investing today in knowledge becomes more attractive).

The firm hires skilled labour up to the point where the marginal cost of hiring (the wage for skilled labour, w_H) equals its marginal product which is the marginal amount of knowledge it generates (G_H) valued at the price of knowledge q:

$$w_H = q\frac{\partial \dot{h}}{\partial H} \tag{4}$$

Similarly, the firm hires unskilled labour up to the point where the marginal cost of hiring (the wage for unskilled labour, w_L) equals its marginal revenue product. Taking into account that the firms demand curve for final goods slopes downward we find:

$$w_L = p\left(1-\frac{1}{\varepsilon}\right)\frac{\partial x}{\partial L} \tag{5}$$

2.3 Short-run partial equilibrium

We now reduce the conditions governing firm behaviour into one equation. We assume that firms are symmetric. Because we normalized the number of firms to one, in equilibrium the representative firm absorbs all labour (L_i=L and H_i=H). The symmetry assumption also implies that h and h_a grow at a common rate, denoted by g, which can be written (from (1)) as:

$$g = \xi h^{-(1-\alpha-\gamma)} H^{\lambda} \tag{6}$$

Assuming that both H and L grow at a common rate n and evaluating the partial derivatives, we find:

$$\frac{w_L}{w_H} \frac{L}{H^{1-\lambda}} \frac{\beta\lambda\xi}{\delta} h^{\alpha+\gamma-1} + (\beta-\gamma)g + (\hat{w}_H - \hat{w}_L) + (\delta-\lambda)n = r - \hat{p} \tag{7}$$

where hats denote growth rates. This equation equates the real cost of capital to the real return to investment. We can use it to study the partial equilibrium short-run effects of an increase in the supply of high skilled labour H by keeping the knowledge level h and the real cost of capital $r-\hat{p}$ constant. Whenever the return to investment increases, there will be an induced demand for skilled labour and hence an upward pressure on their relative wage.

The first term on the lhs represents the *direct* effects of investment for production. If more skilled labour is employed the first term becomes smaller.[11] The reason is that the costs of productivity improvements, relative to production costs, rise with H because of diminishing returns ($\lambda<1$). Hence, a higher supply of skilled labour reduces their relative wage if firms only cared about their ability to improve productivity in production (that is, if only the first term on the lhs mattered). This is the *conventional effect* of an increase in skills.

The other terms on the lhs reflect the effects of knowledge growth on the future relative costs of (or return to) organizational change. Let us first consider the term $(\beta-\gamma)g$. On the one hand, the larger the impact of organizational change, as captured by g, on productivity of unskilled labor, as captured by β, the more attractive it is to invest. Large increases in productivity induce firms to invest now rather than later and increases their demand for the skilled labour to be able to undertake these investments. On the other hand, if knowledge spillovers from other firms are large, knowledge growth results in large reductions over time in the cost of organisational change, which reduces the

[11] If more *un*skilled labour is employed (L higher), the return to investment is higher since more production workers benefit from the same increase in productivity due to the non-rivalness of knowledge. Hence, an increase in unskilled labour raises the demand for skilled labour to undertake the investments which leads to an increase in the skill premium.

incentive to invest now and makes firms willing to postpone investment, thus reducing the demand for skilled labour. If the scope for productivity improvements (β) is large and spillovers (γ) are small, firms are willing to invest more in response to a higher growth rate. Ceteris paribus, this increases demand for skilled labour. Employing more skilled labour increases the rate of productivity growth. Hence, if spillovers are small, this may increase the demand for skills. Thus the demand curve for skilled labour tends to slope upward because of this channel.

The third term on the lhs, the rate of increase in the skill premium, reflects the fact that if skilled labour becomes more expensive to hire over time, investment becomes more expensive over time, and it is attractive to undertake investment now rather than in future. This increases the demand for skills, ceteris paribus.

2.4 General equilibrium

In a closed economy, the cost of capital is determined by savings behaviour of households. Assuming that representative households maximize utility over an infinite horizon subject to their intertemporal budget constraint, we may represent savings behaviour by the familiar Keynes-Ramsey rule:

$$r - \hat{p} = \vartheta + \rho \hat{x} \tag{8}$$

where ρ is the elasticity of marginal consumption which is assumed to be constant ($1/\rho$ is the constant elasticity of intertemporal substitution), ϑ is the utility discount rate.[12] We have employed the fact that total production of the representative firm (x) ends up as consumption goods. This equation expresses the *required rate of return* on households' savings as the sum of the discount rate and the premium for consumption smoothing which depends on the growth of consumption ($\hat{x}$) and the willingness to intertemporally substitute as determined by the curvature of the utility function (ρ).

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[12]We have to correct the discount rate for the growth in the size of the household, which is related to population growth rate n. We specify the intertemporal welfare function as $\int[c^{1-\rho}/(1-\rho)]N^{\nu}e^{-\theta t}dt$, where c is per capita consumption, N is the size of the household which grows at rate n, and ν is the preference for children (note that ν=1 (ν=0) correspond to a Benthamite (Millian) intertemporal utility function, see Canton and Meijdam 1997). The relation between population growth an the pure utility discount rate reads: $\vartheta=\theta-(\nu+\rho-1)n$.

Combining (1), (6), (7) and (8), we find an equation in two unknown variables, viz. the skill premium w_H/w_L and the growth rate g:

$$\left(\rho - (1-\gamma/\beta) - \frac{L}{H}\frac{\lambda}{\delta}\frac{1}{w_H/w_L}\right)\beta g + \vartheta_n = \widehat{w_H/w_L} \qquad (9)$$

where $\vartheta_n \equiv \vartheta + [\lambda + \delta(\rho - 1)]n$.

2.5 The upward sloping demand curve and endogenous growth

We first illustrate the main result of an upward sloping demand curve for skilled labour in a special case of the model. We assume that there are constant returns with respect to knowledge accumulation in the non-production activities, that is $\alpha+\gamma=1$. As a result, the rate of growth in the economy depends on the supply of skilled labour only see (6). To avoid accelerating growth rates, we assume that there is no population growth ($n=0$), the usual assumption in endogenous growth literature.

The model is now fully represented by equation (6) and (9). Figure 1 depicts equation (6) as the vertical line labeled GG. The SS-curve in the figure is the locus for which the skill premium w_H/w_L is constant as can be derived from equation (9). Full employment of skilled labour requires that the economy is always on the GG line. The skill premium jumps immediately to its long-run value, given by the point of intersection between the GG line and the SS curve.

insert Figure 1

We are now ready to analyse the general equilibrium consequences of an increase of the supply of skilled labour for wage inequality. If H increases, the SS-locus shifts down and the GG-line shifts to the right. Hence the change in the skill premium is cannot be unambiguously determined from the Figure. Fortunately, we can easily find a closed form solution for the skill premium. Substituting (6) into (9), and taking into account that $\alpha+\gamma=1$ and that the skill premium is constant, we find:

$$w_H/w_L = \frac{(\lambda/\delta)L}{(\vartheta/\beta\xi)H^{1-\lambda} + [\rho - (1-\gamma/\beta)]H} \tag{10}$$

Differentiation with respect to H reveals that the condition for a rise in the skill premium is given by:

$$\alpha > \rho + (1-\beta)\frac{\gamma}{\beta} + (1-\lambda)\frac{\vartheta}{\beta g} \tag{11}$$

This last condition neatly reveals four determinants that may cause the demand curve for skills to slope upward.

First, appropriability of the (intertemporal) returns to non-production activities (as measured by α) should be high. The mirror image of this is that spillovers to other firms (as measured by γ) should be low. This underlines our key assumption that skilled workers create the knowledge that is subsequently used as an essential input in *non*-production activities. If new knowledge only affects the firm's production activities and all knowledge inputs in non-production activities come from outside (i.e. α=0), condition (12) could never be satisfied and the demand curve for skills sloped conventionally downward. Note that most of the endogenous growth literature consider this case by assuming that all intertemporal spillovers from research are external effects for the individual firm.

Second, the cost of capital should not rise too fast with increased investment. Note from (7) that ρ governs the sensitivity of interest rates with respect to investment. This emphasises the assumption that non-production labour is engaged in the *investment* process, rather than the production process. If firms hire more skilled labour, investment and growth rises in the economy, forcing households to save more. This induces them to require a higher rate of return on their savings, especially when they prefer a smooth consumption pattern (ρ large). When firms face a higher cost of capital, investments in firm-specific knowledge by hiring more skilled labour becomes less attractive. The rise in the cost of capital thus mitigates the demand for skilled labour. For the demand curve for skills to slope upward, the cost of capital should not increase too much which happens if intertemporal substitution is high ($1/\rho$ high).

Third, diminishing returns with respect to knowledge in production (as measured by $1-\beta$) reduce the skill premium. Diminishing returns reduce the value of additions to the knowledge stock which are generated by hiring more skilled labour.[13]

Fourth, diminishing returns with respect to skilled labour in non-production activities (as measured by $1-\lambda$) reduce the skill premium. Diminishing returns reduce the marginal value of skilled labour for the firm and thus depress their wage.

To summarize, an upward sloping demand curve for skills requires that the intertemporal returns from an expansion of non-production activities accrue mainly to the firm rather than to shareholders (in the form of higher rates of return) or other firms (because of spillovers). Moreover, the returns should not fall too quickly because of diminishing returns in production or non-production activities. Only under these circumstances, the firm passes through the intertemporal returns to non-production workers in the form of higher wages for skilled labour.

2.6 The upward sloping demand curve and non-scale growth

We now turn to the more general version of the model and assume that there are diminishing, rather than constant, returns with respect to knowledge in non-production activities, and we take into account population growth ($\alpha+\gamma<1$, $n>0$). The main difference with the case in the previous section is that now long-run growth becomes independent of the size of the skilled labour force. Hence, there is no scale-effect on the growth rate from an increase in the supply of skills. We show that the upward sloping demand curve arises under fairly similar conditions, but vanishes in the long run.

The growth rate depends on the supply of skilled labour and the stock of firms-specific knowledge accumulated in the past, see equation (6). Accordingly, the growth rate

[13]This effect vanishes if there are no spillovers (i.e. if $\gamma=0$). In this case, all knowledge is created inside the firm with constant returns with respect to knowledge (see (2) and note that $\alpha=1-\gamma=1$). On the firm level a constant rate of growth of knowledge can be attained equal to ξH^{λ} which translates in a constant rate of total factor productivity growth equal to $\beta\xi H^{\lambda}$. Hence, diminishing returns are no longer important. In contrast, if the firm relies on outside knowledge ($\gamma>0$), it takes into account that an increase in firm-specific investment *reduces* its rate of knowledge growth for a given rate of growth in the outside knowledge stock h_a. This hurts the firm the more the more important are the diminishing returns in the use of knowledge in production (as measured by $1-\beta$).

is a predetermined variable that changes over time. Differentiating (6) with respect to time yields the equation of motion for the growth rate:

$$\hat{g} = \lambda n - (1-\alpha-\gamma)g \quad (12)$$

Hence the GG locus for constant growth rate reads

$$g=\lambda n/(1-\alpha-\gamma). \quad (13)$$

The SS-locus is the same as in the case of endogenous growth[14] and follows directly from (9). Figure 2 depicts the Phase diagram that results from equations (9) and (12). Transitional dynamics occur along the upward sloping saddle path.

insert Fig 2

To analyse the consequences of an increase in the supply of skilled labour, we now need to distinguish between long-run and short-run effects. For simplicity, we consider a permanent increase in H on t=0, but allow H to grow at rate n at all other dates.

The long-run growth rate is not affected by the supply shock (GG-locus remains unchanged), while the SS-curve shifts down. Hence in the long run, the skill premium unambiguously declines in response to an increased supply of skilled labour.

An increase in skilled labour increases the demand for knowledge inputs in non-production activities on impact. Indeed, the expansion of non-production activities results in an increase in the stock of firm-specific knowledge in the long run (or to be more precise, an increase in knowledge per skilled worker). But, because of diminishing returns in non-production activities with respect to knowledge, this causes the returns to additional knowledge inputs to fall, thus ofsetting the increase in the demand for the skilled labour that produces these knowledge inputs. In the long run, increases in firm-specific knowledge cannot make *non*-production workers more productive because of diminishing returns. Hence, in the long-run, there is no increase in demand for skilled labour for this purpose. In the long run knowledge only makes *production* more productive, and putting in more effort in this sphere requires a fall in the skill premium (the conventional effect).

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[14]Except for the fact that ϑ_n takes a different value because of population growth.

In the short run, however, the growth rate increases by the expansion of non-production jobs. The combination of the shift of the SS locus and the short-run increase of the growth rate produces a (short-run) result that is very similar to that in the endogenous growth case. Indeed, the skill premium may increase in the short run.[15] The difference with the endogenous growth case is that now the (short-run) equilibrium is determined not by the intersection of the SS locus but by the saddle path, which is below the SS locus, thus making an increase in the skill premium less likely. The reason is that firms anticipate a decline in the skill premium (since in the long run the skill premium decreases), that is, they anticipate a decline in the cost of non-production activities. This gives firms an incentive to postpone non-production activities and to reduce the demand for skilled labour. This partly reverses a possible increase in the skill premium.

To derive an exact condition for the upward sloping demand curve to arise, we linearize equations (9) and (12) around the steady state and calculate the short-run response of the skill premium to a change in the supply of skilled labour. The linearized system reads:

$$\begin{bmatrix} \dot{\widetilde{w_H/w_L}} \\ \dot{\tilde{g}} \end{bmatrix} = \begin{bmatrix} a+\vartheta_n & -\vartheta_n \\ 0 & -\lambda n \end{bmatrix} \begin{bmatrix} \widetilde{w_H/w_L} \\ \tilde{g} \end{bmatrix} + \begin{bmatrix} a+\vartheta_n \\ 0 \end{bmatrix} \tilde{H} \qquad (14)$$

where tildes refer to percentage deviations from the initial steady state (log-linearized variables) and $a \equiv \beta g[\rho-(1-\gamma/\beta)]$. From (6) we find the initial change (a time t=0) in the growth rate (which is predetermined):

$$\tilde{g}(0) = \lambda \tilde{H} \qquad (15)$$

where H tilde is the permanent shock to the skill endowment.

The stable root of this system is λn. Hence, we can calculate the jump in the skill premium as:

[15] In the short run -- before the per capita stock of knowledge has fully adjusted -- non-production workers become more productive if more knowledge inputs are available. This gives firms the incentive to hire more labour to produce this knowledge.

$$w_L/w_H(0) \;=\; -\left(\frac{\lambda n + a + (1-\lambda)\,\vartheta_n}{\lambda n + a + \vartheta_n}\right)\tilde{H} \tag{16}$$

The skill premium increases in the short run if the expresion in parenthesis is negative. Taking into account the definition of *a* given above, we find the following condition:

$$\alpha \;>\; \rho \;+\; (1-\beta)\frac{\gamma}{\beta} \;+\; (1-\lambda)\frac{\vartheta_n}{\beta g} \tag{17}$$

Note that this is exactly the same condition as for the endogenous growth case, see (11), although now of course α and γ no longer sum up to unity (and ϑ takes a different value because of population growth). Hence, the very same mechanisms as already explained in the previous case apply.

3. Skilled labour in production

So far we assumed that all skilled labour is allocated to non-production work with an investment character. Though most non-production work is well captured by this perspective, some skilled workers' jobs are more closely related to production. You might for example think of supervision labour and the skilled workers that implement and monitor newly developed quality strategies. In this section we explore the robustness of the upward sloping demand curve for the assumption that some skilled work is closely related to production and hence does not have an investment character.

3.1 Production related skilled work

The production function for final output is now denoted as: $F(h_{xi},L_i)$. The effective organisational quality, h_{xi}, depends now on the mass of skilled workers in activities related directly to production. Hence:

$$h_{xi}=G_1(h_i,H_{xi}) \tag{18}$$

where H_x is skilled labour allocated to production-related activities.[16] Analogously equation (2) is now formulated as:

$$\dot{h}_i = G_2(h_i, h_a, H_{ri}) = \xi h_i^{\alpha} h_a^{\gamma} H_{ri}^{\lambda} \tag{19}$$

H_r is skilled labour in investment related activities. We assume that substitution of (18) in (1) results in the following CES production function:[17]

$$x = Ah^{\beta}\left[\frac{\delta}{\delta+\eta}L^{\frac{\phi-1}{\phi}} + \frac{\eta}{\delta+\eta}H_x^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}(\delta+\eta)} \tag{20}$$

where firm subscripts are supressed. In the next section the model economy is analyzed in the special case that generates endogenous growth, $\alpha+\gamma=1$.

3.2 The demand for skill and capital market equilibrium

The allocation of skilled labour in production adds another first order condition for the solution of the firm's optimisation problem. Firms allocate skilled workers to production-related activities up to the point where the marginal cost of hiring (the wage of skilled workers) equals the marginal revenue. This condition, devided by equation (5), looks like:

$$\frac{L}{H_x} = \left(\frac{\delta}{\eta}\frac{w_H}{w_L}\right)^{\phi} \tag{21}$$

This condition shows more explicitly the *conventional effect* of changes in factor endowments. An increase in the endowment of skilled labour is met by a decrease in the skill premium. Ample substitution possibilities (ϕ large) ease the absorption of skilled workers and hence mitigates the necessary skill premium decrease. Using (21), (6) and the resource constraint, $H_r=H-H_x$, the growth rate can be formulated as:

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[16]In the previous section h_i and h_{xi} were assumed identical.

[17]With ϕ equal to unity we arrive at the Cobb-Douglas production function:

$$x = Ah^{\beta}L^{\delta}H_x^{\eta}$$

$$g = \xi \left(H - L \left(\frac{w_H}{w_L} \frac{\delta}{\eta} \right)^{-\phi} \right)^{\lambda} \tag{22}$$

Remind that we analyse the endogenous growth version of our model, hence $\alpha+\gamma=1$. The growth rate is increasing in the skill premium. A higher relative wage for skilled workers reduces their attractiveness for production-related activities and hence leaves more skilled workers for growth enhancing investment activities. Combining this equation with the no-arbitrage condition (3) yields after some manupulation an implicit equation for the relative wage:

$$\frac{w_H}{w_L} = \frac{\frac{1}{\delta(\delta+\eta)} L \left[\delta + \eta \left(\frac{w_H}{w_L} \frac{\delta}{\eta} \right)^{1-\phi} \right]}{(\vartheta / \beta \xi) + [\rho - (1 - \gamma/\beta)] \left[H - L \left(\frac{w_H}{w_L} \frac{\delta}{\eta} \right)^{-\phi} \right]} \tag{24}$$

This is an analogous expression to equation (10) where λ is set to unity for simplicity. Note that in both the numerator and the denominator a reallocation effect is present. The numerator shows that a higher relative wage affects the value of the production of final output whereas the denominator shows that reallocation of skilled labour affects the value of organisational capital.

Close inspection (or careful application of the implicit function theorem) learns that the sign of the expression in brackets before *H*, that is the sign of $\rho-(1-\gamma/\beta) = \rho+(1-\beta)\gamma/\beta-\alpha$, determined the sign of the effect of an increase in *H* on the skill premium. Hence, we find a similar condition as in the benchmark model (see equation (11) with $\lambda=1$).

4. Conclusion

Wage inequality increased in the 1980s in the majority of OECD countries. In the evaluation of the potential explanations for this phenomenon, trade, technology and relative factor supplies (education), the last explanation was immediately rejected as implausible. The reason for this being that the supply of skilled labour has been increasing throughout the 20th century.

We showed that an increased endowment of skilled labour might induce an increase in the relative wage for skilled labour. The argument that this paper devoloped starts with the explicit recognition that skilled labour or non-production workers perform tasks that are similar to investment activities. That is skilled workers produce firm-specific capital. Once it is recognised that skilled workers use knowledge while producing knowledge an upward sloping demand curve for skill follows, provided that (1) the degree of appropriability of investment in organisational capital is sufficiently large, (2) the investment cost do no rise too fast and (3) diminishing returns related to knowledge accumulation do not set in too stongly.

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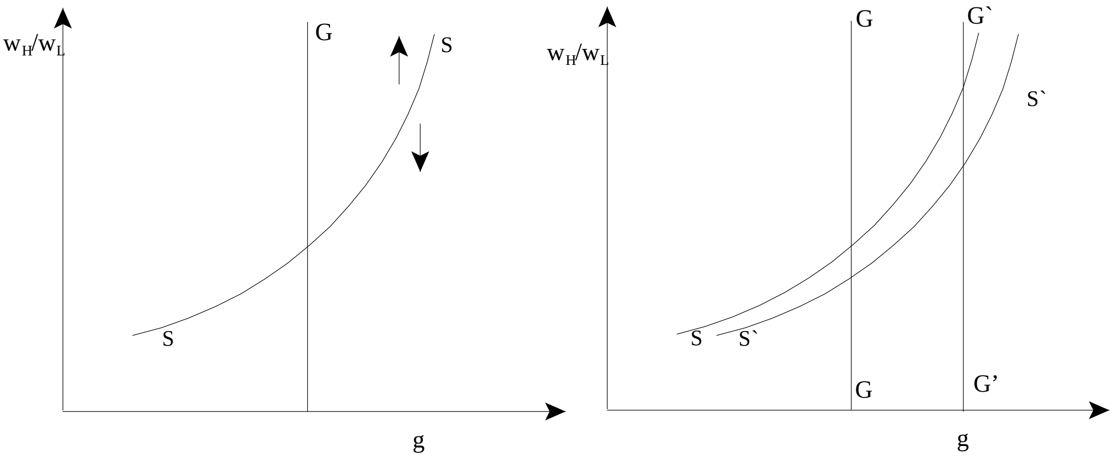

Figure 1.
Endogenous Growth

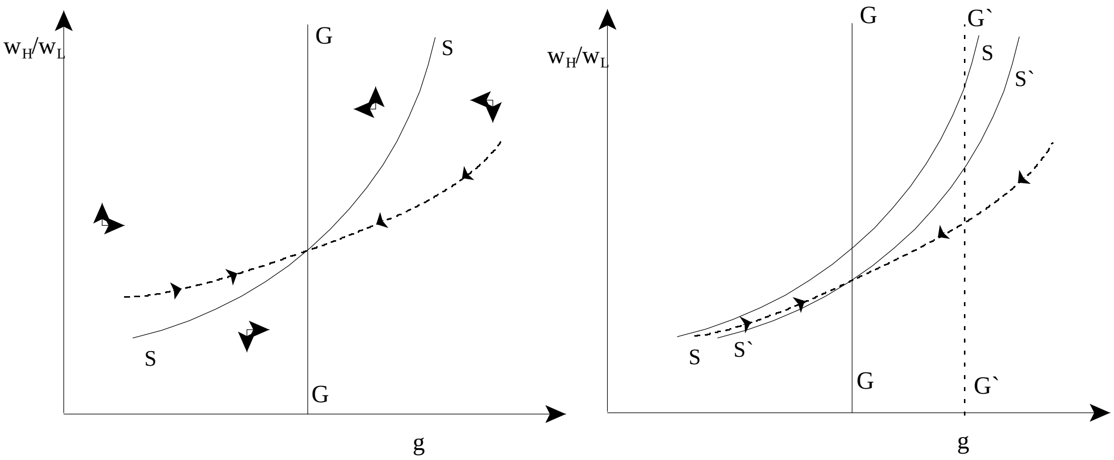

Figure 2. Non-Scale
Growth