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Skill-biased technological knowledge without scale effects

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In the skill-biased technological change literature, the technological-knowledge bias, which drives wage inequality, is determined by the market-size channel. Motivated by the literature on scale effects since Jones (1995a, b), the standard R&D technology is modified so that wage inequality results similarly from the technological-knowledge bias, which is instead induced by the price channel. Thus, by solving the transitional dynamics numerically, it is shown that the recent rise of the skill premium, which is highlighted by, e.g., Acemoglu (2002a), arises from the price-channel effect, complemented with a mechanism that can be called technological-knowledge-absorption effect.

I. Introduction

In Acemoglu (1998, 2002a, b, 2003) and Acemoglu and Zilibotti (2001), for example, labour endowments influence the direction of technological knowledge, which in turn drives the wage inequality dynamics. In these contributions, the chain of effects is dominated by the market-size channel, by which technologies that use the more abundant type of labour are favoured. Therefore, this skill-biased technological change literature has been interpreting the rise in the skill premium as a result of the market-size effect.

Building on this literature, the direction of technological knowledge is analysed in a dynamic setting where, in line with the dominant literature on scale effects since Jones (1995a, b), the scale effects are removed. In particular, it is considered that the difficulty in conducting R&D is proportional to the size of the market measured by the stock of labour, which results in a 'permanent-effects-on-growth' specification (see, e.g., Dinopoulos and Segerstrom, 1999) because technological-knowledge progress and economic growth are endogenous, as opposed to the semi-endogenous models (see, e.g., Jones, 1995b). In this case, however, the chain of effects is induced by the price channel, by which there are stronger incentives to improve technologies when the goods that they produce command higher prices, i.e., technologies are favoured that use the scarcer labour.

For reasons of simplicity, another crucial feature of the model is also reflected in the R&D sector. It is assumed that the capacity to learn, assimilate and implement advanced technological knowledge can be different between types of labour, in line with, e.g., Nelson and Phelps (1966) and Galor and Moav (2000). In this case, the rise in the skill premium results from the fact that the price channel dominates the market-size channel.

In order to better understand the mechanism, a standard (in endogenous R&D-growth theory) economic structure is modelled. The production of perfectly competitive final goods uses labour together with quality-adjusted intermediate goods, which in turn use innovative designs under monopolistic competition.

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In particular, each final good is produced by one of two technologies. One uses high-skilled labour together with a continuum set of high-specific intermediate goods. The other brings together low-skilled labour and a continuum set of low-specific intermediate goods. This production function, with complementarity of inputs and substitutability between technologies, is adapted from Acemoglu and Zilibotti's (2001) horizontal-R&D-growth model with scale effects.

After these introductory remarks, Section II characterizes the economy. Section III analyses the equilibrium and Section IV concludes.

II. Modelling the Domestic Economy

Final goods sector

Following the contribution of Acemoglu and Zilibotti (2001), each final good $n \in [0, 1]$ is produced by one of two technologies. The L-technology uses low-skilled labour, L, complemented with a continuum of L-intermediate goods indexed by $j \in [0, J]$. The H-technology's inputs are high-skilled labour, H, complemented with a continuum of H-intermediate goods indexed by $j \in [J, 1]$. The output of n, Y_n, at time t is,

$$Y_n(t) = A\left\{\left[\int_0^J \left(q^{k(j,t)} x_n(k,j,t)\right)^{1-\alpha} dj\right][(1-n)l\,L_n]^\alpha + \left[\int_J^1 \left(q^{k(j,t)} x_n(k,j,t)\right)^{1-\alpha} dj\right][n\,hH_n]^\alpha\right\}. \quad (1)$$

The term A is a positive exogenous variable representing the level of productivity, dependent on the country's institutions. The integrals sum up the contributions of intermediate goods to production. In the Schumpeterian tradition, the quantity of each j, x, is quality-adjusted – the constant quality upgrade is $q > 1$, and k is the highest quality rung at time t. The expressions with exponent $\alpha \in [0, 1]$ represent the role of the labour inputs. An absolute productivity advantage of H over L is accounted for by $h > l \geq 1$. A relative productivity advantage of either type of labour is captured by the terms n and $(1-n)$, which implies that H is relatively more productive in final goods indexed by larger ns, and vice-versa. As we can be seen below, at each time t there is a competitive equilibrium threshold final good $\bar{n}$, where the switch from one technology to the other becomes advantageous.

Plugging the demand for the highest quality of each intermediate good j by the representative producer of n into Equation 1, the supply of final good n is

$$Y_n(t) = A^{1/\alpha}\left[\frac{p_n(t)(1-\alpha)}{p(j,t)}\right]^{(1-\alpha)/\alpha} \times [(1-n)l\,L_n\,Q_L(t) + n\,h\,H_n\,Q_H(t)], \quad (2)$$

where

$$Q_L \equiv \int_0^J q^{k(j,\,t)[(1-\alpha)/\alpha]}\,dj \text{ and } Q_H \equiv \int_J^1 q^{k(j,\,t)[(1-\alpha)/\alpha]}\,dj \quad (3)$$

are two aggregate quality indexes, measuring the technological knowledge in each range of intermediate goods, adjusted by market power that is the same for all monopolistic producers;[1] and where $p_n(t)$ and $p(j,t)$ are the prices of n and of j, respectively.

The aggregate output, i.e., the composite final good, is defined as:

$$Y(t) \equiv \int_0^1 p_n(t)\,Y_n(t)dn = \exp\left[\int_0^1 \ln\ Y_n(t)dn\right], \quad (4)$$

where its price is normalized at each time t to one.[2] Resources in the economy measured in terms of aggregate output, Y, can be used in the production of intermediate goods, X, in the R&D sector, R, or consumed, C; i.e., $Y(t) = X(t) + R(t) + C(t)$.

Intermediate goods sector

Since the aggregate output is the input in the production of $j \in [0, 1]$ and final goods are produced in perfect competition, the marginal cost of producing j is one. The production of j requires a start-up cost of R&D, which can only be recovered if profits at each date are positive for a certain time in the future. This is assured by a system of intellectual property rights that protect the leader firm's monopoly, while at the same time, disseminating, almost without costs, acquired technological knowledge to other firms. Thus, technological knowledge on how to make j tends to be public.

The profit-maximization price of the monopolistic intermediate good firms yields $p(k,j,t) = p = 1/(1-\alpha)$, which represents a mark-up, since $p > 1$. The closer α is to zero, the smaller the mark-up and

[1] Thus, the ratio $D \equiv Q_H/Q_L$ is the relative productivity of the technological knowledge used together with H.
[2] That is, the composite final good is numeraire.

thus there is less room for monopoly pricing. This mark-up is constant over time, across intermediate goods and for all quality grades, which makes the problem symmetric. Since the leader firm is the only one legally allowed to produce the highest quality, it will use pricing to wipe out sales of lower quality.

Depending on whether $q(1-\alpha)$ is greater or lesser than marginal cost, the leader firm will use either the monopoly pricing $p = 1/(1-\alpha)$ or the limit pricing $p = q$, respectively, to capture the entire market. Like Grossman and Helpman (1991, Ch. 4), for example, it is assumed that limit pricing strategy is binding and thus is used by all firms. Since the lowest price that the closest follower can charge without negative profits is one, the leader can successfully capture the entire market by selling at a price slightly below q, as q is the quality advantage over the closest follower. Thus, q is also an indicator of the market power of the incumbent firm in each intermediate good.

R&D sector

The value of the leading-edge patent depends on the profit-yields accrued by the monopolist at each time t, and on the duration of the monopoly. The duration, in turn, depends on the probability of successful R&D, which creatively destroys the current leading-edge design. The determinants of the probability of success are thus at the heart of the Schumpeterian R&D models (see, e.g., Aghion and Howitt, 1992).

Let $pb(k, j, t)$ denote the instantaneous probability at time t – a Poisson arrival rate – of successful innovation in the next quality intermediate good j, $k(j, t) + 1$, which complements m-type labour (where $m = L$ if $0 \leq j \leq J$ and $m = H$ if $J < j \leq 1$). Formally,

$$pb(k,j,t) = rs(k,j,t) \cdot \beta q^{k(j,t)} \cdot \zeta^{-1} q^{-\alpha^{-1} k(j,t)} \cdot m^{-1} \cdot f(j), \tag{5}$$

where:

(i) $rs(k, j, t)$ is the flow of aggregate final-good resources devoted to R&D, which defines the framework as a lab-equipment model (e.g., Rivera-Batiz and Romer, 1991).

(ii) $\beta q^{k(j,t)}$, $\beta > 0$, represents learning by R&D, as the positive learning effect of accumulated public technological knowledge from past successful research (see, e.g., Grossman and Helpman, 1991, Ch. 12; and Connolly, 2003).[3] Thus, β is the coefficient on past successful R&D experience, where a greater β depicts a better innovation capacity.

(iii) $\zeta^{-1} q^{-\alpha^{-1} k(j,t)}$, $\zeta > 0$, is the adverse effect, i.e., cost of complexity, caused by the increasing complexity of quality improvements (see, e.g., Kortum, 1997). Hence, ζ corresponds to the fixed cost of R&D.

(iv) The positive learning effect (ii) is modelled in such a way that, together with the complexity cost (iii), totally offsets the positive influence of the quality rung on the profits of each intermediate good leader firm, as can be seen below. This is the technical reason for the presence of the production function parameter α in Equation 5.

(v) m^{-1} is the adverse effect of market size, capturing the idea that the difficulty in introducing new quality-adjusted intermediate goods and replacing old ones is proportional to the size of the market measured by the labour employed.[4] That is, for simplicity, the costs of scale increasing are reflected in R&D due to co-ordination among agents, processing of ideas, informational, organizational, marketing and transportation costs, as suggested by works such as Becker and Murphy (1992), Alesina and Spolaore (1997), Dinopoulos and Segerstrom (1999) and Dinopoulos and Thompson (1999).[5]

(vi) $f(j)$ captures an absolute advantage of the high-skilled labour over the low-skilled labour to learn, assimilate and implement advanced technological knowledge, i.e., it can be called a technological-knowledge-absorption effect. Hence, again for simplicity, the difference between types of labour in their ability to adapt to new technological knowledge is also reflected in the R&D sector. A possible specification for function $f(j)$ is

$$f(j) = \begin{cases} 1 & \text{if } 0 \leq j \leq J; \quad \text{i.e., } m = L \\ \left(1 + \dfrac{H}{H+L}\right)^{\sigma} & \text{if } J < j \leq 1; \quad \text{i.e., } m = H \end{cases},$$

$$\text{where: } \sigma = 1 + \frac{H}{L}. \tag{6}$$

[3] It is essential to distinguish between this learning effect and the conventional learning-by-doing, which is usually formulated as the decline of production costs induced by the cumulative experience of production.

[4] As stated, Dinopoulos and Segerstrom (1999) call this the 'permanent-effects-on-growth' specification.

[5] Dinopoulos and Thompson (1999), in particular, provided micro-foundations for this effect in a model of growth through variety accumulation.

Generically this term is similar to the skill-biased technology adoption effect emphasized in Nelson and Phelps (1966) and Schultz (1975), and more recently in Galor and Tsiddon (1997), Greenwood and Yorukoglu (1997) and Galor and Moav (2000), among others. This term is also motivated by works such as: (i) Benhabib and Spiegel (1994), who suggest labour can enhance innovation capacity; (ii) Hassler and Rodriguez-Mora (2000), who claim that ability or intelligence, i.e., skill, is crucial in adapting to new technologies; and (iii) Parent and Prescott (1994), who stress a large number of barriers to technological-knowledge adoption such as regulation, legal constraints, corruption, organizational change, political instability and resistance from workers.

Consumers

A time-invariant number of heterogeneous individuals – continuously indexed by $a \in [0,1]$ – decide the allocation of income, which is partly spent on consumption of the composite final good, and partly lent in return for future interest. For simplicity, an exogenous threshold individual $\bar{a}$ is considered, such that individuals $a > \bar{a}$ are high-skilled, whereas individuals $a \leq \bar{a}$ are low-skilled. The infinite horizon lifetime utility of an individual with ability a is the integral of a discounted CIES utility function,

$$U(a,t) = \int_0^\infty \left[\frac{c(a,t)^{1-\theta} - 1}{1-\theta}\right] \exp(-\rho t) dt, \qquad (7)$$

where: (i) $c(a,t)$ is the amount of consumptions of the composite final good by the individual with ability a, at time t; (ii) $\rho > 0$ is the homogeneous subjective discount rate; and (iii) $\theta > 0$ is the inverse of the inter-temporal elasticity of substitution.

The budget constraint of individual a equalizes income earned to consumptions plus savings, at each t. Savings consists of accumulation of financial assets – K, with return r – in the form of ownership of the firms that produce intermediate goods in monopolistic competition. The value of these firms, in turn, corresponds to the value of patents in use. The budget constraint, expressed as savings = income − consumptions, is

$$\dot{K}(a,t) = r(t)K(a,t) + w_m(t)\, m(a) - c(a,t), \qquad \text{where:} \begin{cases} m = H & \text{if } a > \bar{a} \\ m = L & \text{if } a \leq \bar{a} \end{cases} \qquad (8)$$

and w_m is the price paid for a unit of m-type labour.

Each individual maximizes lifetime utility (Equation 7), subject to the budget constraint (Equation 8). The solution for the consumption path, which is independent of the individual, is the standard Euler equation:

$$\hat{c}(t) = \frac{r(t) - \rho}{\theta}, \qquad (9)$$

where $\hat{c}(t)$ is the growth rate of c.

III. Equilibrium

Equilibrium for given factor levels

With perfect competition in final goods, economic viability of either type of technology depends on the relative productivity, h/l, and price of the m-type labour, as well as on the relative productivity and prices of the intermediate goods, because of complementarity in production. The prices of labour rely on the quantities, H and L. In relative terms, the productivity-adjusted quantity of H in production is $(hH)/(lL)$. As for the productivity and prices of intermediate goods, they depend on complementarity with either m-type labour, H or L, on the technological knowledge embodied and on the mark-up. These determinants are summed up in the aggregate quality indexes, Q_L and Q_H, in Equation 3.

The endogenous threshold final good $\bar{n}$ follows from equilibrium in the inputs markets and relies on the determinants of economic viability of the two technologies:[6]

$$\bar{n}(t) = \left\{1 + \left[\frac{Q_H(t)}{Q_L(t)} \frac{hH}{lL}\right]^{1/2}\right\}^{-1}. \qquad (10)$$

It can be related to prices bearing in mind that on the threshold both an L- and H-technology firm should break even. This yields the ratio of index prices of final goods produced with L- and H-technologies,

$$\frac{p_H(t)}{p_L(t)} = \left[\frac{\bar{n}(t)}{1 - \bar{n}(t)}\right]^\alpha,$$

where:

$$\begin{cases} p_L = p_n(1-n)^\alpha = \exp(-\alpha)\bar{n}^{-\alpha} \\ p_H = p_n n^\alpha = \exp(-\alpha)(1-\bar{n})^{-\alpha} \end{cases}$$
$$\text{since} \quad \exp \int_0^1 \ln p_n \, dn = 1. \qquad (11)$$

[6] Thus, H-technology is used in final goods $n > \bar{n}$ and L-technology in final goods $n \leq \bar{n}$.

Equation 10 shows that if either the technology is highly H-biased or if there is a large relative supply of H, the fraction of final goods using the H-technology is large and $\bar{n}$ is small. By Equation 11, small $\bar{n}$ implies a low relative price of final goods produced with H-technology. In this case, the demand for H-intermediate goods is low, which discourages R&D activities aimed at improving their quality, as can be seen below. Thus, labour structure affects the direction of R&D through the price channel, which appears in various papers by Acemoglu (e.g., 2002a), although always dominated by the market-size channel. In the present case, this latter channel is removed and, consequently, becomes absent.

The equilibrium aggregate resources devoted to intermediate-goods production, X, and the equilibrium aggregate output, Y, i.e., the composite final good in Equation 4, are expressible as a function of the currently given aggregate quality indexes,

$$\begin{aligned} X(t) \equiv \int_0^1 \int_0^1 x_n(k,j,t)dj\,dn &= \exp(-1) \\ &\times \left[\frac{A(1-\alpha)}{q}\right]^{1/\alpha} \\ &\times \left[(Q_L(t)\,l\,L)^{1/2} + (Q_H(t)\,h\,H)^{1/2}\right]^2; \end{aligned} \tag{12a}$$

$$\begin{aligned} Y(t) \equiv \int_0^1 p_n(t)\;Y_n(t)dn &= \exp(-1)\,A^{1/\alpha} \\ &\times \left[\frac{1-\alpha}{q}\right]^{(1-\alpha)/\alpha} \\ &\times \left[(Q_L(t)\,l\,L)^{1/2} + (Q_H(t)\,h\,H)^{1/2}\right]^2. \end{aligned} \tag{12b}$$

The price paid for a unit of m-type labour, w_m, is equal to its marginal product. From Equation 12b, the equilibrium growth rate of w_m and the equilibrium H-premium, W (a measure of intra-country wage inequality), are, at each time t, respectively:

$$\hat{w}_m = \frac{1}{\alpha}\hat{p}_m + \hat{Q}_m \quad \text{and} \quad W \equiv \frac{w_H}{w_L} = \left(\frac{Q_H h\,L}{Q_L l\,H}\right)^{1/2}. \tag{13}$$

Equilibrium R&D

The expected current value of the flow of profits to the monopolist producer of intermediate good j, $V(k,j,t)$,[7] relies on the profits at each time, $\Pi(k,j,t)$,[8] on the given equilibrium interest rate and on the expected duration of the flow, which is the expected duration of the successful research's technological-knowledge leadership. Such duration, in turn, depends on the probability of a successful R&D. The expression for $V(k,j,t)$ is

$$V(k,j,t) = \frac{\Pi(k,j,t)}{r(t) + pb(k,j,t)}. \tag{14}$$

Hence, the expected income generated by the successful research on rung kth at time t, $V(k,j,t)r(t)$, equals the profit flow, $\Pi(k,j,t)$, which is paid out as dividends, minus the expected capital loss, $V(k,j,t) \times pb(k,j,t)$, which will occur when the kth rung is replaced by a new one. Thus, $r + pb$ is the effective discount rate of the successful R&D on rung k.

Under free-entry R&D equilibrium the expected returns are equal to resources spent,

$$pb(k,j,t)\;V(k+1,j,t) = rs(k,j,t). \tag{15}$$

The equilibrium can be translated into the path of technological knowledge. The following expression for the equilibrium m-specific growth rate (where the equilibrium m-specific probability of successful R&D, pb_m, given r and p_m is plugged in) is obtained:

$$\begin{aligned} \hat{Q}_m(t) = &\left\{\frac{\beta}{\zeta}\left(\frac{q-1}{q}\right)(p_m(t)A(1-\alpha))^{1/\alpha}\bar{m}f(\cdot) - r(t)\right\} \\ &\times \left[q^{(1-\alpha)/\alpha} - 1\right]. \end{aligned} \tag{16}$$

In Equation 16, the term in large brackets, pb_m, turns out to be independent of j and k due to the removal of all scale effects. On the one hand, the positive influence of the quality rung on profits and on the learning effect is completely offset by its effect on the complexity cost. On the other hand, scale effects could arise through market size, as discussed since Jones (1995a, b). Since the study aims at stressing the price channel, the adverse effect of market size due to the scale-proportional difficulty of introducing new quality intermediate goods is designed to offset the scale effect on profits. Indeed, computing $pb_H - pb_L$, the direction taken by technological-knowledge progress is determined by the price channel.

The equilibrium aggregate resources devoted to R&D, R, at each time t, are

$$R \equiv \int_0^1 rs(k,j)dj = \frac{\zeta}{\beta}\left\{Q_L\,L\,pb_L + Q_H\,H\,pb_H\right\}. \tag{17}$$

[7] *I.e.*, $V(k,j,t)$ is the market value of the patent or the value of the monopolist firm, owned by consumers.

[8] $\Pi(k,j,t) = \bar{m}m(q-1)\left[\frac{p_m(t)A(1-\alpha)}{q}\right]^{1/\alpha} q^{k(j,t)\alpha^{-1}(1-\alpha)}$, $\bar{m} = h$ for $m = H$ and $\bar{m} = l$ for $m = L$.

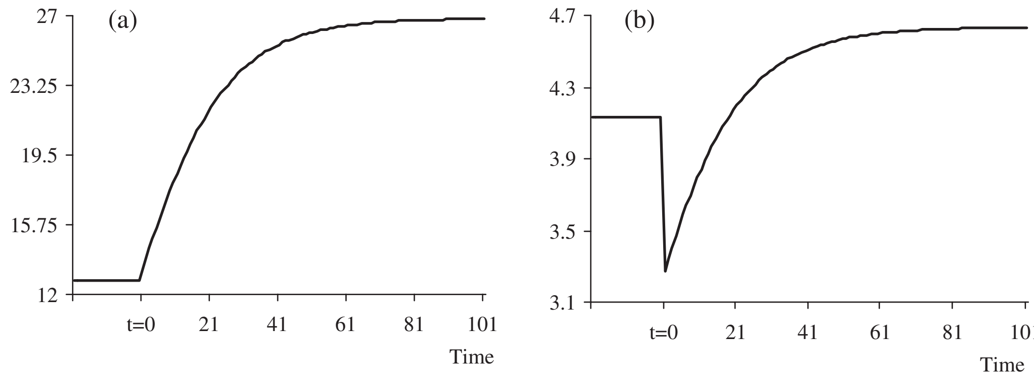

Fig. 1. Transitional dynamics of (a) The technological-knowledge bias and (b) The *H*-premium

Hence, Equation 17 shows that more resources devoted to R&D are needed as Q_L and/or Q_H, for example, rise(s) to offset the greater difficulty of R&D when Q_L and/or Q_H increase(s).

Steady state

Since the aggregate output has constant returns to scale in inputs – see Equation 12b – and Y, X, R and C are all multiples of Q_H and Q_L,[9] the constant and unique steady-state endogenous growth rate, which through the Euler equation (Equation 9) also implies a constant steady-state interest rate, $r^*(=r_L^*=r_H^*)$, designed by $g^*(=g_L^*=g_H^*)$ is:

$$g^*=\hat{Q}_L^*=\hat{Q}_H^*=\hat{Y}^*=\hat{X}^*=\hat{R}^*=\hat{C}^*=\hat{c}^* =\frac{r^*-\rho}{\theta}\Rightarrow \hat{p}_H^*=\hat{p}_L^*=\hat{\bar{n}}^*=0. \tag{18}$$

Thus, r^* is obtained by setting the growth rate of consumption in Equation 9 equal to the growth rate of technological knowledge in Equation 16, and then g^* results from plugging r^* into the Euler equation (Equation 9). One can also find p_m^* and $\bar{n}^*$ by equalling the steady-state growth rates of Q_H and Q_L. Also from Equation 18, it is found that: (i) $\hat{w}_m^*$ rises steadily and in proportion to the technological-knowledge progress, $\hat{w}_m^*=\hat{Q}_L^*=\hat{Q}_H^*$; and (ii) the H-premium remains constant, $\hat{w}_H^*-\hat{w}_L^*=\hat{Q}_H^*-\hat{Q}_L^*=0$.

Transitional dynamics and sensitivity analysis

Since the aim is to analyse the direction of technological-knowledge progress and its repercussion on H-premium, one can use Equation 16 to obtain the required differential equation. Given that the interest rate is always unique, one has:

$$\hat{D}(t)=\frac{\beta}{\zeta}\left(\frac{q-1}{q}\right)(A(1-\alpha))^{1/\alpha}\exp(-\alpha) \times\left\{h\left(1+\frac{H}{H+L}\right)^{\sigma}\left[1+\left(D(t)\frac{hH}{lL}\right)^{-1/2}\right]^{\alpha} -l\left[1+\left(D(t)\frac{hH}{lL}\right)^{1/2}\right]^{\alpha}\right\}. \tag{19}$$

First, one can thus verify the stability of the relative productivity of the technological knowledge used together with H, $D\equiv Q_H/Q_L$ (a technological-knowledge bias measure). Then, the behaviour of other variables can be characterized, namely the H-premium in Equation 13.

Using the fourth-order Runge-Kutta classical numerical method,[10] the study presents technological knowledge's precise time path for a set of baseline parameter values and for a set of baseline labour endowments in Appendix A (Table A1). Figures 1a and 1b summarize the main results. They compare the baseline steady-state paths of, respectively, the technological-knowledge bias, D, and the H-premium, W, with the ones resulting from an exogenous increase (at time $t=0$) in high-skilled labour (from 0.9 to 1.5). The table in Appendix B (Table B1) compares initial and steady-state values of D and W under different scenarios.

Due to the increase in high-skilled labour, the technological-knowledge-absorption effect is greater than in the baseline scenario – note that $f(j)$ in Equation 6 jumps immediately from 2.089 to 3.238

[9] Considering Equations 12a, b and 17 and then solving the aggregate resource constraint for aggregate consumption: $C=Y-X-R$, it is found that in equilibrium Y, X, R and $C\equiv\int_0^1 c(a)da$ are all multiples of Q_H and Q_L.

[10] Since this classical method solves the differential equation with suitable precision, more sophisticated methods need not be considered.

as a result of a move from $H = 0.9$ to $H = 1.5$. This heightens the technological-knowledge bias in favour of H-intermediate goods (see Fig. 1a). Such bias increases the supply of H-intermediate goods, thereby increasing the number of final goods produced with H-technology – see Equation 10 – and lowering their relative price – see Equation 11. Thus, relative prices of final goods produced with H-technology drop continuously towards the constant steady-state levels. This path of relative prices implies that the technological-knowledge bias is increasing, from $D^{*}_{Baseline} = D(t = 0) = 12.784$, but at a decreasing rate until it reaches its new higher steady state, $D^{*} = 26.810$ (see Fig. 1a).

Figure 1b shows that an increase of high-skilled labour causes an immediate drop in the H-premium, at time $t = 0$, from $W^{*}_{Baseline} = 4.129$ to $W = 3.198$. This is because an increase in H raises its relative supply and lowers its relative wage – see Equation 13. In other words, the H-premium falls instantly due to the rise in the supply of high-skilled labour without new endogenous technological-knowledge progress and so without change in technological-knowledge bias. This result also occurs in Acemoglu's (2002a) model and is empirically supported by the recent work of Choi and Jeong (2005).

By reason of complementarity between inputs in Equation 1, changes in the H-premium are closely related to the technological-knowledge bias, as Equation 13 clearly shows. As the increase in the supply of high-skilled labour induces technological-knowledge bias, the immediate effect on the level of the H-premium ends up being reverted in the transition towards the steady state. That is, the stimulus to the demand for H, arising from the technological-knowledge bias, increases the H-premium, which is also in line with Choi and Jeong (2005). Once in steady state, with a constant technological-knowledge bias, the H-premium remains constant. Moreover, one must highlight that with a sufficiently strong technological-knowledge-absorption effect, as in the present case, the steady-state H-premium is greater than that which has prevailed under the baseline case, $W^{*} = 4.632 > W^{*}_{Baseline} = 4.129$.

In summary, instead of the market-size channel emphasized by the skill-biased technological change literature, another mechanism is proposed to explain the increase in the H-premium even when the relative supply of high-skilled labour has also increased.

IV. Conclusion

Instead of the market-size channel emphasized by the skill-biased technological change literature, another explanation is offered for skill-biased technological knowledge, which drives wage inequality. The essential idea is again that the same economic forces (profitability of R&D) that affect the amount of technological-knowledge progress will also shape the technological-knowledge bias. In the skill-biased technological change literature, the stock of labour is connected to the size of profits that in each period accrue to the leader producer: a larger market expands the monopolist's profits and, thus, the incentives to allocate resources to R&D, thereby directing technological knowledge. However, in addition to theoretical arguments, several authors have supplied the debate with empirical evidence against scale effects (see, e.g., Jones, 1995a). Consequently, the scale effects are removed and a new mechanism proposed: the technological-knowledge-absorption effect by which the pool of labour influences the rate of technological-knowledge progress and, thus, determines the technological-knowledge bias.

Left with only the price channel, an increase in high-skilled labour expands the technological-knowledge-absorption effect, which, in turn, strongly re-directs R&D towards designs that improve the quality of intermediate goods used together with high-skilled labour. As a result, the relative productivity of these intermediate goods increases, diminishing the perfectly competitive domestic relative prices of final goods produced with this technology. Then, through the price channel, the technological-knowledge bias increases but at a decreasing rate until it reaches its new higher steady state.

With regard to wage inequality, it is found that an increase in high-skilled labour causes an immediate steep drop in the high-skilled premium since its relative supply decreases its relative wage. This immediate effect is reverted in the transitional dynamics towards the constant steady-state high-skilled premium, due to the stimulus to the demand for high-skilled labour resulting from the technological-knowledge bias. It is interesting to note that this path of wage inequality is in line with the recent work of Choi and Jeong (2005). Moreover, one notes also that with a sufficiently strong technological-knowledge-absorption effect, the steady-state high-skilled premium is greater than the previous one.

The framework is still quite stylized as the study deals with only one country, no horizontal R&D, and only follower firms that support R&D. This encourages extensions in several directions. For example, with two or more countries both intra and inter-country wage inequality can be analysed and under different international trade regimes.

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Appendix A: Baseline Parameter Values and Baseline Labour Endowments

Parameters and labour endowments in the baseline case are chosen to calibrate the steady-state growth rate around 2%, which approximately matches the average per capita growth rate of the US in the post-war period (see, e.g., Jones, 1995b). For some parameters the choice is guided by empirical findings, whereas other parameter values are based on theoretical specification. When the range of choice is large, a value close to some critical value is preferred, the idea being to stay within a 'consensus benchmark'.

Table A1. Baseline parameter values and baseline labour endowments

Parameter	Value
A	1.50
h^{a}	1.20
l^{a}	1.00
α^{b}	0.70
q^{b}	3.33
β^{a}	1.60
ζ^{a}	4.00
θ^{c}	1.50
ρ^{d}	0.02
H^{a}	0.90
L^{a}	1.00
σ^{a}	1.90

Notes: [a] The values are in accordance with the theoretical assumptions, such that: (i) $h > l \geq 1$ – see Equation 1; (ii) $\beta > 0$ – see Equation 5; (iii) $\zeta > 0$ – see Equation 5; and (iv) $\sigma = 1 + H/L$ – see Equation 6.
[b] Assuming the particular case $q = 1/(1–\alpha)$, α has two interpretations: the labour share, α, and the mark-up ratio, $1/(1-\alpha)$. Its value is in line with its common use to calibrate models with physical capital accumulation and fixed labour. Moreover, as the mark-up interpretation is central in the present case, given the value of α, q is equal to 3.3(3), which is set in line with the mark-up estimates in, e.g., Kwan and Lai (2003).
[c] The baseline value for θ is coherent with the recent attempts at its estimation (see, e.g., Hall, 1988). Moreover, the value $\theta \in [1, 2]$ is the most common range of values considered (see, e.g., Attanasio and Weber, 1993).
[d] The value for ρ, for a time period of one year, is also set in line with previous works on growth (see, e.g., Dinopoulos and Segerstrom, 1999).
Source: Author's assumptions, based on theoretical framework and on the literature.

Appendix B: Main Results of Transitional Dynamics and Sensitivity Analysis

Table B1 shows that the higher technological knowledge is reached in scenario 3. It is also in this scenario that the steep drop in W at time zero is more pronounced and where the steady-state H-premium is greater: $W^{*}_{Scenario\ 3} > W^{*}_{Scenario\ 2} > W^{*}_{Scenario\ 1} > W^{*}_{Baseline} = 4.129$.

Table B1. Comparing initial and steady state values of the variables

	Three different scenarios					
	Scenario 1, $H = 1.1$		Scenario 2, $H = 1.3$		Scenario 3, $H = 1.5$	
Variable	Initial	Steady state	Initial	Steady state	Initial	Steady state
D	12.784	15.967	12.784	20.499	12.784	26.810
W	3.734	4.174	3.435	4.350	3.198	4.632

Source: Author's computations.