The Growth Effect of Cross-Sectoral Distortions

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Abstract

In a multi-sector model of Schumpeterian growth with intersectoral spillovers in (labor intensive) research and development, the equilibrium rate of growth depends upon the steady state distribution of relative sales across vintages. Comparing balanced growth paths, I show that policies that skew sales in favor of innovations increase the rate of growth, even if they depress sales of all goods in absolute terms.

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1 Introduction

This paper presents a property of the multi-sector model of Schumpeterian growth with labor intensive research and development (R&D). Differently from the model by Grossman and Helpman (1991), the one by Aghion and Howitt (1998a, p.85-92) allows profits to vary across producers of goods produced with different technologies. I generalize this model to analyze changes in the relative competitiveness of goods of different technological age. Changes of the distribution of relative competitiveness across vintages may depend directly or indirectly on public policies, such as discriminatory taxation or subsidies. The distribution of relative competitiveness affects incentives to engage in R&D and therefore the equilibrium rate of growth. In fact, a policy that skews sales in favor of innovations, typically, fosters the rate of growth.

The analysis is restricted to balanced growth paths. The next section presents the model. In the following section I analyze the impact of permanent changes in the distribution of sales across goods of different technological age, and present an example. In the conclusion I explain which assumptions are crucial for the result, discuss related literature, and propose some fields of application.

2 The model

Consider the multi-sector version of the vertical innovations paradigm of growth by Aghion and Howitt (1998a, p.85-92). Production takes place in three steps. The competitive final sector employs labor and a continuum (of unit mass) of intermediate goods supplied by monopolistically competitive firms. The latter are protected by patents in producing the good with the highest productivity within their sector. Competitive R&D firms produce patents employing labor. Labor, N, is a fixed factor, and $n \in [0, N)$ denotes R&D employment, which is constant on a balanced growth path.

Assume a unit mass of R&D firms, each of which targets a productivity improvement on a particular intermediate good, and obtains an innovation with a Poisson arrival rate $\phi(n)$ (with $\phi' > 0$, $\phi'' \leq 0$, $\phi(0) = 0$). The successful firm sells the patent to produce an intermediate good, characterized by the highest productivity across the economy at the date of innovation, denoted by $\bar{A}$ and called the leading edge technology (an intersectoral spillover). The local monopolist producing the latest generation of the good is not constrained by competition from the incumbent producer.[1] The leading edge technology —a proxy for public knowledge— grows continuously at a rate that depends on aggregate R&D activity (an intertemporal spillover):[2]

$$g_{\bar{A}} = f(n) \tag{1}$$

with $f' > 0$, $f'' \leq 0$, $f(0) = 0$. Arbitrage in R&D implies that if $n > 0$, the marginal cost of R&D (the wage, w) equals the marginal expected return:[3]

$$w_\tau = \phi'(n) V_\tau \tag{2}$$

where V_τ is the value of an innovation arrived at date τ, i.e.:

$$V_\tau = \int_\tau^\infty e^{-r(t-\tau)} \pi\left(\bar{A}_\tau, t\right) e^{-\phi(n)(t-\tau)} dt$$

The integrand includes (i) the discount factor, (ii) the stream of future profits, π, of a monopolist with technology $\bar{A}_\tau$, (iii) the survival probability of the monopoly.

The production function of the final sector is Cobb-Douglas in labor and intermediate goods, x_j with $j \in [0,1]$:

$$Y = (N-n)^{1-\alpha} \int_0^1 A_{j\tau} x_{j\tau}^\alpha dj$$

[1]These assumptions imply that the payoff to innovation is independent of the sector where it is implemented, so that R&D is uniform across sectors at equilibrium.

[2]I denote the instantaneous growth rate of variable y by $g_y = \dot{y}/y$.

[3]R&D firms do not take into account the effect of increased R&D on the value of the patent, because the latter depends on the expected future R&D in the aggregate economy, on which the current activity of single R&D firms has no influence.

where $\alpha \in (0,1)$ and $A_{j\tau}$ is the productivity index of good j at date τ. Given decreasing returns, all goods with the same productivity are used in the same quantity. To evaluate the integral, it is useful to reshuffle goods according to their technological age $s \in [0,\infty]$, and write output in the form $Y = (N-n)^{1-\alpha} \int_0^\infty A_s x_s^\alpha h(s) ds$, where A_s denotes the productivity and $h(s)$ the mass of goods of age s. Any technology is applied initially to a mass $\phi(n)$ of goods, out of which only a proportion $e^{-\phi(n)s}$ survives at date τ, hence $h(s) = \phi(n)e^{-\phi(n)s}$. Aggregate output is normalized in terms of output produced using the leading edge good $\bar{Y} = (N-n)^{1-\alpha} \bar{A}\bar{x}^\alpha$. The productivity gap of goods of age s is $A_s/\bar{A}_\tau = \bar{A}_{\tau-s}/\bar{A}_\tau = e^{-f(n)s}$ from (1). Let $Q(s,\tau) = (x_s/\bar{x}_\tau)^\alpha$ define the competitiveness index of goods of age s relative to the leading edge good, to write:

$$Y_\tau = \bar{Y}_\tau \phi(n) \int_0^\infty e^{-f(n)s} Q(s,\tau) e^{-\phi(n)s} ds \tag{3}$$

The value of an innovation of date τ is normalized with respect to the leading edge good. The inverse demand for this good is $\bar{p} = \alpha (N-n)^{1-\alpha} \bar{A}\bar{x}^{\alpha-1}$. Denoting by $\bar{m}$ its marginal cost, the monopolist optimally charges the price $\bar{p} = \bar{m}/\alpha$, to obtain profits $\bar{\pi} = (1-\alpha)\alpha (N-n)^{1-\alpha} \bar{A}\bar{x}^\alpha$.[4] Let $Q^+(t,\tau) = (x_t/\bar{x}_\tau)^\alpha$ be the function describing the evolution of competitiveness of goods with productivity $\bar{A}_\tau$.[5] Then, the value of an innovation of date τ is:

$$V_\tau = \bar{\pi}_\tau \int_\tau^\infty e^{-r(t-\tau)} Q^+(t,\tau) e^{-\phi(n)(t-\tau)} dt \tag{4}$$

General equilibrium is determined by the labor-market clearing condition. As shown below, at equilibrium the relative competitiveness function is time invariant. This means that at any date τ the relative competitiveness of goods of age s is the same as the competitiveness of the leading edge good of date τ in $t = s$ time lag relative to its present level.

[4] The marginal cost is allowed to vary over time. Intermediate goods can be produced using output, capital or some fixed factor.

[5] $x_t = X(\bar{A}_\tau, t)$ defines the sales of a good with technology $\bar{A}_\tau$ at dates $t \geq \tau$.

Proposition 1 *If $f(n) \neq r$, the competitiveness function $Q(.)$ is independent of time, and the equilibrium R&D employment is the solution to:*

$$\frac{\phi(n)/\phi'(n)}{\alpha\,(N-n)}\int_0^\infty e^{-[f(n)+\phi(n)]s}Q(s)ds = \int_0^\infty e^{-[r+\phi(n)]t}Q(t)dt \tag{5}$$

Proof: The labor-market clears if, at full employment, wages paid in the final sector and in R&D coincide. The wage in the final sector is the marginal product of labor $w_\tau = (1-\alpha)Y_\tau/(N-n)$, and using (3):

$$w_\tau = \frac{1-\alpha}{N-n}\bar{Y}_\tau\phi(n)\int_0^\infty e^{-f(n)s}Q(s,\tau)e^{-\phi(n)s}ds \tag{6}$$

Using (6), (4) and $(1-\alpha)\bar{Y}_\tau/\bar{\pi}_\tau = 1/\alpha$, equation (2) is:

$$\frac{\phi(n)/\phi'(n)}{\alpha\,(N-n)}\int_0^\infty e^{-[f(n)+\phi(n)]s}Q(s,\tau)ds = \int_\tau^\infty e^{-[r+\phi(n)](t-\tau)}Q^+(t,\tau)dt \tag{7}$$

This condition must hold unchanged at all dates τ for n to be constant. Consider first its left-hand-side. The first factor and the exponential in the integrand are independent of τ. The left-hand-side is constant over time only if $Q(.)$ is also independent of τ. Turning to the right-hand-side of (7), the exponential is also independent of the date τ (the rate of interest being constant along a balanced growth path). Therefore, also the prospective competitiveness function, Q^+, is independent of τ. Hence, along a balanced growth path $\forall s \equiv t$:

$$Q(s) = \left(\frac{x_s}{\bar{x}}\right)^\alpha \equiv Q^+(t) = \left(\frac{x_t}{\bar{x}}\right)^\alpha \equiv Q\,(.) \tag{8}$$

The two competitiveness schedules, one backward and the other forward looking, must coincide. Condition (5) results from (7) and (8). ■

Let me now turn to the properties of the equilibrium. First, the growth rate of aggregate output is an increasing function of the level of R&D employment, as long as the following is satisfied:[6]

Assumption 1: $f'(n) > \alpha\partial g_{\bar{m}}/\partial n$.

In particular, aggregate output grows at the same rate as the leading edge technology, $g_Y = f(n)$, whenever the quantity sold by innovators is constant, $g_{\bar{x}} = 0$

[6]Sales of the leading edge good are $\bar{x} = (N-n)(\alpha^2\bar{A}/\bar{m})^{1/(1-\alpha)}$. Thus $g_{\bar{x}} = (g_{\bar{A}}-g_{\bar{m}})/(1-\alpha)$. From (3) and (8), the rate of growth of output is equal to that of $\bar{Y}$, i.e. $g_Y = (f(n)-\alpha g_{\bar{m}})/(1-\alpha)$. Hence: $\partial g_Y/\partial n > 0 \Leftrightarrow \alpha\partial g_{\bar{m}}/\partial n < f'(n)$. This assumption is reasonable if the distinction between R&D and production is meaningful.

(i.e. $\bar{m}/\bar{A}$ is constant). I impose the following assumption for the sake of briefness:

Assumption 2: $r = h(g_Y) > g_Y$, with $\partial h/\partial g_Y \geq 0$.

All these properties can be derived as results, by modeling the saving behavior of a representative infinitely lived household. In particular in the latter case, the property $r > g_Y$ holds at equilibrium to ensure that the optimized path of savings is non trivial, as it would if the agent's income increases at a higher rate than the rate of interest. It is the no-Ponzi game condition (Blanchard and Fisher, 1998 ch.2), and it plays a crucial role in the proof of the next proposition.

The two sides of the equilibrium condition (5) are depicted in figure 1 and represent the relative demand for labor from the final sector (LHS) and from the R&D sector (RHS) respectively. It can be shown that the former is increasing in n, while for the latter to be decreasing it is sufficient that the following condition be satisfied together with assumption 1:[7]

Assumption 3: $\partial Q(.)/\partial n \leq 0$.

If LHS¡RHS at $n = 0$, the equilibrium is unique.

The characterization of the equilibrium which is peculiar to the present analysis lies in property (8). This result is quite intuitive: it means that the distribution of market shares across goods of different ages is constant. This is a distinctive feature of the equilibrium in a multi-sector economy.

Corollary *If $f(n) \neq r$, any permanent change in the competitiveness function, $Q(.)$, has an impact on the equilibrium level of R&D activity, n, and therefore on*

[7] From (2) and (4) we have that $LHS = w_\tau/(\phi'(n)\bar{\pi}_\tau)$, thus the LHS is increasing in n:

$$\frac{\partial LHS}{\partial n} = \frac{\phi'(n)\bar{\pi}_\tau\left(\partial w_\tau/\partial n\right) - w_\tau\left(\phi''(n)\bar{\pi}_\tau + \phi'(n)\left(\partial\bar{\pi}_\tau/\partial n\right)\right)}{(\phi'(n)\bar{\pi}_\tau)^2} > 0$$

since (i) $\partial w_\tau/\partial n > 0$ because of diminishing returns with respect to labor; (ii) $\phi'' < 0$ by assumption; (iii) $\partial\bar{\pi}_\tau/\partial n < 0$ because the less labor is employed in production, the lower is the demand for any intermediate good. Under assumptions 1 and 2 the RHS is decreasing in n, as the exponential and $Q(.)$ in the integrand are non increasing in n.

the growth rate.

Proof: If $Q(.)$ changes permanently the two sides of (5) are affected differently because $f(n) \neq r$. ■

3 Changes in relative competitiveness

This section develops the corollary above. It first presents a general result and then an example.

Consider the case when the relative competitiveness of goods of different technological age can be affected by appropriate policies. Defining the policy as the continuous variable P, the relative competitiveness index can be expressed as function of P, $Q(P,s)$ or $Q(P,t)$. Suppose that the policies do not affect directly ϕ, f or r.[8] It is possible to analyze their impact on the equilibrium R&D employment and the growth rate of the economy by studying how the two sides of the equilibrium condition (5) respond to changes in policy.

Proposition 2 *Suppose that assumptions 1 and 3 are satisfied and at equilibrium, $r > f(n)$ then a policy that skews the relative competitiveness schedule towards innovations increases R&D employment and growth at equilibrium if its impact is biased against older vintages:*

$$\frac{\partial Q(P,s)}{\partial P} < 0 \quad and \quad \left| \frac{d\left(\frac{\partial Q(P,s)/\partial P}{Q(P,s)}\right)}{ds} \right| > 0 \quad \Rightarrow \quad \frac{\partial n}{\partial P} > 0 \quad and \quad \frac{\partial g}{\partial P} > 0$$

Proof: Suppose that P changes from an initial value P_0, implying an equilibrium n_0. Since assumptions 1 and 3 imply that $dLHS/dn > 0$ and $dRHS/dn < 0$, we have:

$$\begin{aligned} \frac{\partial LHS}{\partial P}\Big|_{n=n_0} &= \frac{\phi(n_0)/\phi'(n_0)}{\alpha(N-n_0)} \int e^{-[f(n_0)+\phi(n_0)]s} \frac{\partial Q(P,s)}{\partial P} ds \\ &< \int e^{-[r(n_0)+\phi(n_0)]t} \frac{\partial Q(P,t)}{\partial P} dt = \frac{\partial RHS}{\partial P}\Big|_{n=n_0} \quad \Rightarrow \quad \frac{dn}{dP} > 0 \end{aligned} \tag{9}$$

[8]The policy affects the value of ϕ, f and r through its impact on the equilibrium level of R&D, n

Consider any positive discount rate, δ, and let $\Psi(.)$ be the normalized weight function:

$$\Psi(\delta, u) = \frac{e^{-\delta u} Q(P, u)}{\int_0^\infty e^{-\delta v} Q(P, v) dv}$$

$\Psi(\delta, u)$ has a fixed pivot at $\tilde{u}$, i.e.: $\exists\ \tilde{u}$ unique such that $d\Psi/d\delta > 0\ \forall u < \tilde{u}$ and $d\Psi/d\delta < 0\ \forall u > \tilde{u}$. In fact simple calculus gives:

$$\frac{d\Psi}{d\delta} = \Psi(\delta, u) \left[\frac{\int_0^\infty v e^{-\delta v} Q(P, v) dv}{\int_0^\infty e^{-\delta v} Q(P, v) dv} - u \right]$$

hence $\tilde{u} = \left[\int_0^\infty v e^{-\delta v} Q(P, v) dv\right] / \left[\int_0^\infty e^{-\delta v} Q(P, v) dv\right]$.

Around the original equilibrium, n_0, we can use (5) to substitute for

$$\frac{\phi(n_0)/\phi'(n_0)}{\alpha(N - n_0)} = \frac{\int_0^\infty e^{-[r+\phi(n_0)]t} Q(P, t) dt}{\int_0^\infty e^{-[f(n_0)+\phi(n_0)]s} Q(P, s) ds}$$

into (9) to obtain the inequality:

$$L = \int_0^\infty \Psi(\delta_1, s) \frac{\partial Q(P, s)/\partial P}{Q(P, s)} ds < \int_0^\infty \Psi(\delta_2, t) \frac{\partial Q(P, t)/\partial P}{Q(P, t)} dt = R \qquad (10)$$

where $\delta_1 = f(n_0) + \phi(n_0) < \delta_2 = r + \phi(n_0)$ if $r > f(n)$. If $\forall t$ or s $\partial Q(P, .)/\partial P < 0$, (10) is true if $-L > -R > 0$, which is the case if $-(\partial Q(P, .)/\partial P)/Q(P, .)$ is an increasing function, given that $\delta_1 < \delta_2$ implies that $\Psi(\delta_2, t)$ puts more weight on early events (i.e. for $t < \tilde{t} \equiv \tilde{u}$) than $\Psi(\delta_1, t)$.[9] ■

The proposition specifies the conditions under which the two sides of (5) shift downwards as in figure 1, with the LHS falling more than the RHS. R&D employment must increase for the equilibrium to be restored. The condition $r > f(n)$ is not particularly restrictive. In fact, I have argued that the property of assumption 2, $r > g_Y$ is in general satisfied. Let me now argue that $g_Y \approx f(n)$ is the most plausible case. Since the cross-sectoral distribution of sales is stationary, the average productivity of intermediate goods grows at the same rate as the productivity of the leading-edge good. Therefore, aggregate output grows at a

[9] If $\forall t$ or s instead $\partial Q(P, .)/\partial P > 0$, (10) is true if $0 < L < R$, which is the case if $(\partial Q(P, .)/\partial P)/Q(P, .)$ is a decreasing function given that $\delta_1 < \delta_2$ implies that $\Psi(\delta_2, t)$ puts more weight on early events (i.e. for $t < \tilde{t}$) than $\Psi(\delta_1, t)$.

lower rate than the rate of growth of the average productivity of intermediate goods only if the fall in employment of some other input reduces sales of the leading edge good in absolute terms. This is for instance the case of polluting emissions in Ricci (2001). Yet it is unlikely that problems of absolute scarcity produce a significant divergence between g_Y and $f(n)$, such that $f(n) > r > g_Y$.

3.1 An example: pure discrimination across vintages

Recall from the aggregate production function of the final sector that the inverse demand functions for intermediate goods $j \in [0, 1]$ are $p_j = \alpha (N - n)^{1-\alpha} A_j x_j^{\alpha-1}$. Local monopolists will thus sell $x_j = (\alpha^2 A_j / m_j)^{\frac{1}{1-\alpha}} (N - n)$, where m represents the marginal cost. Assume that intermediate goods are produced using capital according to the technology $x_j = K_j / A_j$, so that the marginal cost equals rA_j without government intervention. Consider instead a policy that taxes producers at a rate σ_j, modifying the marginal cost to $m_j = (1 + \sigma_j) rA_j$.[10] As in the previous section it is convenient to reshuffle goods according to their age. Using equivalent notation we have:

$$Q(s, \tau) = \left(\frac{1 + \bar{\sigma}_\tau}{1 + \sigma_s} \right)^{\frac{\alpha}{1-\alpha}} \quad \text{and} \quad Q^+(t, \tau) = \left(\frac{1 + \bar{\sigma}_\tau}{1 + \sigma_t} \right)^{\frac{\alpha}{1-\alpha}}$$

With a stationary policy, such that $\forall \tau \ \sigma_s \equiv \sigma_t$ if $s \equiv t$, the functions coincide and simplify to:

$$Q(s) = \left(\frac{1 + \bar{\sigma}}{1 + \sigma_s} \right)^{\frac{\alpha}{1-\alpha}}$$

The simplest possible policy, relatively favorable to innovations, is defined by a the couple $\{T, \omega\}$, where T is the age at which the tax rate increases and $1/\omega$ measures the spread in marginal costs between young and old vintages:

$$Q(s) = \begin{cases} 1 & \forall s < T \\ \omega < 1 & \forall s \geq T \end{cases}$$

[10] To simplify the exposition we abstract from the government budget constraint $\int_0^1 \sigma_j A_j r x_j dj = 0$, which is equivalent to assuming that lump sum transfers are feasible.

In this case the equilibrium condition (5) is:

$$\tilde{L} \equiv \frac{\phi(n)/\phi'(n)}{\alpha(N-n)} \frac{1-(1-\omega)\, e^{-[f(n)+\phi(n)]T}}{f(n)+\phi(n)} = \frac{1-(1-\omega)\, e^{-[r+\phi(n)]T}}{r+\phi(n)} \equiv \tilde{R}$$

An increase in the spread, i.e. in $(1-\omega)$, shifts downwards both sides of the equation.[11] However around the original equilibrium (at n_0) $\tilde{L}$ falls more than $\tilde{R}$ since $r > f(n)$.[12] Suppose, for instance, that the tax rate is left unchanged on new equipment, but it is increased for older ones. The policy measure increases the cost of production of older intermediate goods and reduces the use of capital. As a result the productivity of labor and the demand for labor from the final sector fall. This tends to depress the equilibrium wage and the cost of R&D. Yet, the higher tax rate also reduces the prospective flow of profits accruing to innovators, and hence the value of an innovation at equilibrium. As shown in figure 1, however, at the original equilibrium level the latter (proportional to $\tilde{R}$) falls less than the wage (proportional to $\tilde{L}$). Hence R&D employment must increase for the equilibrium to be restored. Appendix 4 provides an example of a policy that does not modify the position of the RHS schedule but leads to similar implications.

The asymmetric impact of the policy measure on relative labor demand from the final sector and from the R&D sector is obvious. In fact, lower sales of older

[11] Notice that this case encompasses a number of different policies. For instance, ω may fall when both tax rates are increased or both reduced, as well as when either the tax rate on older vintages is increased or the one on younger vintages is reduced.

[12] In fact:

$$\left.\frac{\partial \tilde{L}}{\partial(1-\omega)}\right|_{n=n_0} = -\frac{\phi(n_0)/\phi'(n_0)}{\alpha(N-n_0)} \frac{e^{-[f(n_0)+\phi(n_0)]T}}{f(n_0)+\phi(n_0)} < -\frac{e^{-[r+\phi(n_0)]T}}{r+\phi(n_0)} = \left.\frac{\partial \tilde{R}}{\partial(1-\omega)}\right|_{n=n_0} < 0$$

Substituting for $\frac{\phi(n_0)/\phi'(n_0)}{\alpha(N-n_0)}$ using the equilibrium condition, the inequality implies:

$$\frac{1-(1-\omega)\, e^{-[r+\phi(n_0)]T}}{1-(1-\omega)\, e^{-[f(n_0)+\phi(n_0)]T}} > \frac{e^{-[r+\phi(n_0)]T}}{e^{-[f(n_0)+\phi(n_0)]T}}$$

which is satisfied if $r > f(n)$, since this implies that the left hand side of the last inequality is larger than unity, while the second is smaller.

intermediate goods decrease labor productivity and labor demand in the final sector according to the contribution of older goods to production, and ultimately to their productivity gap ruled by (1). The value of an innovation falls because innovators expect to be taxed at a higher rate in the future. However, this expected decline in the future stream of profits affects the value of the innovation according to the discount factor, which depends on the interest rate. Hence there is no reason for the change in demand for labor from the two sectors to be proportional. Ultimately, an implication of the result is that future events (as the decline in prospective profits) have a smaller influence on the present conditions of the labor market than past events (the distribution of productivity across equipment in use, summarizing the historical path of technological change).

To grasp the intuition of the result it can be useful to recall that in models of endogenous growth with capital accumulation, there is a positive correlation between the productivity of capital and the equilibrium growth rate of the economy. In this example, the policy biases sales towards new capital goods on a permanent basis, reducing the average age of equipment in use and increasing the average productivity of capital. Hence the return on capital increases, fostering investment, and more investment leads to faster growth.

4 Concluding remarks

The result holds on the basis of two crucial assumptions. First, it is assumed that the cost of R&D is affected by the relative competitiveness function. In fact the cost of R&D is the wage, and the relative use of different goods determines the average productivity of intermediate inputs, and therefore the productivity of labor in the final sector. This is why, in the equilibrium condition (5), both the cost of and the reward to R&D depend on the competitiveness function. In the absence of this symmetry the result is radically different. Suppose, for instance, that R&D inputs consist of output, so that the marginal cost of R&D is constant.[13] Then only an increase in the value of innovations fosters R&D activity.

The other crucial assumption lies in the intersectoral R&D spillover and in the absence of competition from incumbent producers. They allow profits to be heterogenous across goods of different vintages, and make sense of the relative competitiveness function. Other models of growth do not retain this realistic feature. In the horizontal innovations model of growth by Romer (1990), all local monopolists share the same productivity, demand and profits. In this case, the index of relative competitiveness is equal to unity for any vintage. Heterogeneity across goods plays no role either in the quality-ladder model by Grossman and Helpman (1991). They do not consider the intersectoral spillover in R&D and must thus suppose that incumbents compete permanently with entrants to ensure that local monopolists' profits and R&D investment are uniform across sectors. The value of innovations is then characterized by a flat competitiveness function ($Q^+(t) = 1$), while the wage depends on the cross-sectoral relative competitiveness, which however is given exogenously by initial conditions and it is invariant at steady state.

A variety of policies can affect the distribution of market shares across vintages. Some policy measures favor directly innovations as they enter the market, such as fiscal incentives for new firms or for the adoption of new equipment. Other policies affect the competitiveness of relatively old sectors, for instance support schemes for declining sectors. Patenting regulation and antitrust policy affect the returns to innovative activity by their impact on the relative market shares of innovators. A policy that biases demand across sectors can be defined as "demand management", albeit in a rather unusual sense within our discipline.

[13] Equal to unity in this case because we have normalized the price of output.

In this framework targeted public purchase programs can influence the distribution of market shares in hte absence of perfect crowding out. Unintended policies may also have an indirect impact on growth if they bias demand across sectors. Ricci (2000) considers the case when new goods are relatively clean. A tax on emissions of pollutants skews relative demand in favor of new goods and fosters innovation, and as a result it may increase growth.

Appendix: another example

Consider a policy that discriminates between old and young vintages as in the example of section 3.1, but with the statutory objective of leaving the normalized value of innovations unchanged, at the original equilibrium level of R&D employment. The policy change considered consists of the following: (i) leaving the tax on vintages younger than T unchanged at $\bar{\sigma}$; (ii) increasing the tax on older vintages; (iii) delaying date T to compensate for increased taxation and ensure that V is unchanged at the original n_0. Using (4) and the definition of the policy we have:

$$\begin{aligned} V_\tau &= \bar{\pi}_\tau \left[\int_0^T e^{-[r+\phi(n)]t} dt + \omega \int_T^\infty e^{-[r+\phi(n)]t} dt \right] \\ &= \frac{\bar{\pi}_\tau}{r+\phi(n)} \left[1 - (1-\omega) e^{-[r+\phi(n)]T} \right] \end{aligned}$$

where, using the equilibrium value of $\bar{x}_\tau$, $\bar{\pi}_\tau = \bar{A}_\tau (1-\alpha) \alpha^{\frac{2}{1-\alpha}-1} (N-n) [(1+\bar{\sigma})r]^{\frac{-\alpha}{1-\alpha}}$ is independent of T and of the tax rate levied on older vintages, σ_T, hence it is not directly affected by the policy change. Instead the policy is defined as follows. First the impact of a change in the spread in marginal costs on the value of patents is:

$$\left. \frac{dV_\tau}{d\omega} \right|_{n=n_0} = \frac{\bar{\pi}_\tau}{r+\phi(n_0)} e^{-[r+\phi(n_0)]T} \left[1 + [r+\phi(n_0)] (1-\omega) \frac{\partial T}{\partial \omega} \right]$$

and hence, imposing $dV_\tau/d\omega|_{n=n_0} = 0$ we obtain $\partial T/\partial \omega = -[(r+\phi(n_0))(1-\omega)]^{-1}$. Since the right-hand side of the equilibrium condition is proportional to the expected marginal value of R&D employment, $\phi'(n)V_t$, its schedule does not move. Hence we can understand how the equilibrium level of R&D employment is affected by the policy measure by analyzing its impact on the schedule of the left-hand side of the equilibrium condition, that is proportional to the locus of the inverse demand for labor from the final sector. Proceeding as in the previous case, one gets:

$$w_\tau = \frac{(1-\alpha)}{(N-n)} \frac{\bar{Y}_\tau \phi(n)}{[f(n)+\phi(n)]} \left[1-(1-\omega)\, e^{-[f(n)+\phi(n)]T}\right]$$

Thus:

$$\left.\frac{dw_\tau}{d\omega}\right|_{n=n_0} = \frac{(1-\alpha)}{(N-n_0)} \frac{\bar{Y}_\tau \phi(n_0)}{[f(n_0)+\phi(n_0)]} e^{-[f(n_0)+\phi(n_0)]T} \left[1+[f(n_0)+\phi(n_0)]\,(1-\omega)\frac{\partial T}{\partial \omega}\right]$$

and taking into account that T is adjusted to leave the value of innovations unchanged, we have:

$$\left.\frac{dw_\tau}{d\omega}\right|_{n=n_0} = \frac{(1-\alpha)}{(N-n_0)} \frac{\bar{Y}_\tau \phi(n_0)}{[f(n_0)+\phi(n_0)]} e^{-[f(n_0)+\phi(n_0)]T} \left[1-\frac{f(n_0)+\phi(n_0)}{r+\phi(n_0)}\right] > 0$$

since $r > f(n_0) \equiv g_Y$. This means that an increase in the spread unfavorable to older vintages (a fall in ω), though conceived to be neutral with respect to the value of innovations, does instead favor R&D activity by depressing the demand for labor from the final sector, hence freeing labor inputs towards R&D. In graphical terms, the downward-sloping schedule representing the RHS of the equilibrium condition does not move, while the upward-sloping schedule of its LHS shifts downwards, so that their intersection moves rightward at a higher level of R&D employment, n.

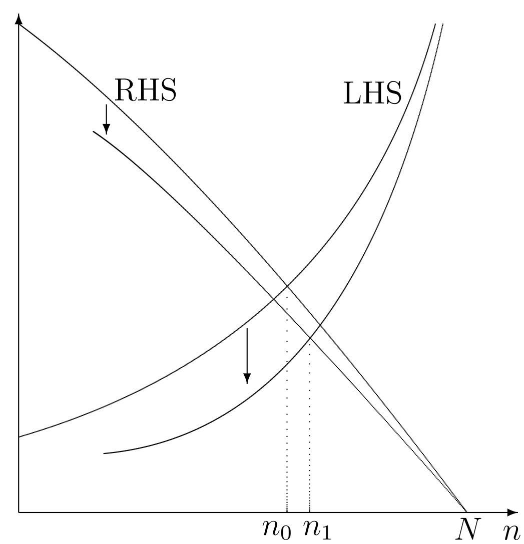

Figure 1. The equilibrium condition:

effect of a cross-sectoral distortion relatively favorable to innovations

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