UNIVERSITÀ DEGLI STUDI DI ANCONA
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Horizontal Innovation, Market Power and Growth

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Horizontal Innovation, Market Power and Growth

di Alberto Bucci[†]

Abstract

In this paper, we build a general model of horizontal product innovation and economic development, taking explicitely into account the most relevant insights stemming from the recent literature on this topic. What results from our analysis is that, when innovation is both deterministic and horizontal, the relationship between market power and aggregate growth is not robust at all. We also find that not only technology, but also the intersectoral competition for human capital, matters for growth. This is particularly relevant in terms of public policies aimed at the strategic allocation of skilled workers to the different sectors of the economy.

Keywords: Horizontal Product Differentiation, Market Power, Technological Change, Endogenous Growth.
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1. Introduction

Can market power be really considered as *"the price"* that a society as a whole is called to pay in order to have a more dynamically efficient economic system?

The schumpeterian answer to this question would be certainly positive, the *"monopoly power"* being considered as the reward accruing to the successful innovator from his/her innovative activity (Aghion, Dewatripont and Rey, 1997). More precisely, in the Schumpeterian tradition (J. Schumpeter, 1942), the bigger this reward is the larger the incentives to innovate will also be, with the consequence that, within this particular research line, (ex-post) market power is generally considered as an important stimulus to the R&D-activity *(first schumpeterian hypothesis)* and, as such, it should importantly contribute to increase output over time[1].

Obviously, the major premise to this point of view is that the knowledge and R&D capital really matters for growth.

Such a result seems to be fully confirmed by most of empirical evidence on the modern economic systems growth experience[2]. Indeed, Fagerberg (1988), Lichtenberg (1992), Gittleman and Wolff (1995) and Verspagen (1996), among others, have recently shed a significative light on the positive correlation existing in the long run between technological variables and GDP growth. In particular, an important result stemming from the work by Gittleman and Wolff (1995) is also that the R&D activity allows to account for the cross-country differences in the aggregate productivity growth rates *only* when the analysed sample consists of the more advanced economies. As far as the medium/low income countries are concerned, the effect

[1]many recent studies in the field of the *Economics of Innovation* have indeed shown that a higher concentration in the product market makes the results of the innovative activity more easily *appropriable* by private agents, so fostering their decisions of investment in R&D capital. In this respect, Aghion and Howitt (1997) write: *"...(product market competition)...reduces the size of monopoly rents that can be appropriated by successful innovators, and therefore diminishes the incentive to innovate"* (p. 284).

[2]the empirical literature analysing the relationship between innovative activity and productivity growth (not only at the macroeconomic level) is practically boundless. However, important synthesis of it can be found in Griliches (1979, 1992), BLS (1989) and, more recently, Monhen (1992) and Keely and Quah (1998).

of R&D on the aggregate growth seems to be almost negligible, the development of these countries being a process mainly driven by variables other than the "technological" ones.

However, another branch of applied literature (in the field of *technological diffusion*) convincingly shows either that the technological spillovers are quantitatively very relevant and that they positively affect the developing countries growth. One of the more recent and significative contributions in this area is certainly the one by Coe, Helpman and Hoffmaister (1997), who show that: i) on average, a one percent point increase in R&D expenses of the more advanced economies determines a 0.06% increase in the output of the developing countries; ii) the main *"propagation channel"* of technological spillovers is international trade, allowing the developing countries to use a broader variety of intermediate goods, to imitate more easily the new technologies incorporated in them and, eventually, to increase more rapidly the productivity of their own resources.

In brief, the innovative activity seems to play empirically a central role in boosting the long-run wealth of nations (not only directly, but also, we would say, indirectly, thanks to the diffusion of the so-called technological spillovers).

On the theoretical side, the recent resurgence of the original Schumpeterian idea, linking positively innovation to growth, is due to a large extent to the birth and subsequent diffusion of the so called *"R&D-Based Growth Models"*. Such approaches (mainly Aghion and Howitt, 1992; Grossman and Helpman, 1991; Romer, 1990a) move from the assumption that the defining characteristic of technology is non-rivalry[3].

The explicit introduction of such an hypothesis is not at all innocuous for the theory of growth. In fact, this specific technology attribute (non-rivalry) makes the production possibility set of an

[3] it is Romer himself (1990b, p.97) to define what is to be meant by *"non-rival input"*: *"...there are (at least) two ways to think about nonrival inputs. One is to treat a good like a design or a list of instructions as something that is distinct from the medium on which it is stored, and to say that it can be used simultaneously by arbitrarily many different firms and people. A more litaral way to describe a nonrival good is to treat the physical medium containing the design or instructions as the relevant good. Then a nonrival input has a high cost of producing the first unit and a zero cost of producing subsequent units"*.

economy non convex and, since the pure competitive equilibrium is no more sustainable, calls for the explicit introduction into the analysis of the concept of market power, the real innovation spur (Romer, 1991).

Although the R&D-Based Growth Models share both the same starting point[4] and the same way of viewing an economic system[5], they arrive at substantially different conclusions as far as the sign of the relationship between market power and growth is concerned.

In this respect, the aim of this paper is twofold.

Firstly, we intend to show that, contrary to the Aghion and Howitt (1992) model, whenever innovation takes the shape of a deterministic horizontal expansion of the existing varieties of intermediate inputs, the *monopoly power - aggregate growth* relationship becomes ambiguous. In particular, we show that such a relationship can be either positive or negative depending on the absolute dimension of the monopoly power enjoyed by the successfull innovator, on the type of technology currently used in the downstream sector (producing the consumer good) and, finally, on the intensity of *intersectoral competition for the acquisition of the fixed supply relevant input* (human capital)[6].

Secondly, we also intend to show how the interaction between two of the three elements just mentioned above (the kind of inputs each industry employs in order to obtain its own output and the way in which these inputs are combined) may influence the level of the economy steady-state growth rate.

On the basis of these motivations, the article is organized in the following way: in section two we introduce the model and illustrate

[4] the explicit inclusion of imperfect competition among those factors potentially able to influence the growth performance of a country.

[5] this one is generally divided into three productive sectors: a competitive homogeneous final output sector, an imperfectly competitive intermediate inputs sector and an industrial research sector.

[6] Aghion and Howitt (1992, 1997, 1998), on the contrary, point out that when technological change is explicitely assumed to be not deterministic and to take the shape of a continuous improvement in the quality of the existing goods (vertical differentiation), *"...product market competition is unambiguously bad for growth"* (Aghion and Howitt, 1997, p. 284).

the main characteristics of the economic system we take into consideration; in section three we study separately the impact that the type of technology (Cobb Douglas vs CES) currently used in the final output sector and the kind of inputs entering in it have both on the *mark-up/growth relationship* and the level of the economy steady-state growth rate.

In the paragraph 3.1 we also propose some policy implications stemming from the model and the last section concludes.

2. A General Model of Horizontal Deterministic Product Innovation and Endogenous Growth.

The economy we propose in our model is qualitatively similar to the one present in the standard models of innovation-driven growth (Aghion and Howitt, 1992; Grossman and Helpman, 1991, chapters 3 and 4; Romer, 1990a). In particular, we imagine an economic system made up of three sectors, producing respectively an homogeneous consumption good, N different varieties of technologically advanced goods and knowledge. We also assume that the total supply of skilled (H) and unskilled (L) labour is exogeneously fixed and that L (unskilled labour) is exclusively used in the downstream sector, whereas H (skilled labour) may be employed (with the same productivity) in each sector of the economic system under examination.

Contrary to the Aghion and Howitt (1992) and Grossman and Helpman (1991, chapter 4), in our set-up innovation is a perfectly deterministic activity and takes the shape of an expansion in the set of the currently produced intermediate inputs (horizontal differentiation). Contrary to the Romer (1990a) and Grossman and Helpman (1991, chapter 3) models, we write the technology in use in the consumer good sector in a more general way and as a function of two parameters (λ and ϕ). Depending on the values these two parameters assume, we are able to exactly reproduce the two models just mentioned and many other situations we will discuss in the next section. At the same time, writing the final output sector technology in the more general way we

propose allows us to highlight the role different production functions (Cobb-Douglas vs CES; with or without human capital) play both on the monopoly power/growth relationship and the equilibrium growth rate level.

• *The production of the consumption good.*

The final output sector is competitive and is characterised by the following constant returns to scale technology:

$$(1)\ Y_t = L^{\phi(1-\lambda)} \cdot (H_{Y_t})^{(1-\phi)(1-\lambda)} \cdot \left[\sum_{j=1}^{N_t} (x_{jt})^{\alpha}\right]^{\frac{\lambda}{\alpha}}, 0 \le \phi \le 1; \quad \lambda \ge 0; 0 \le \frac{\lambda}{1+\lambda} < \alpha < 1$$[7].

(From now on, in order to ease the notation, the index t, near the variables depending on time, will be omitted unless this may induce confusion).

In (1), the symbols used have the following meaning: Y_t is total output at t; L is the total (and constant) amount of non skilled labour; H_{Y_t} is the stock of human capital employed at t for producing Y; x_j is the quantity of the j-th variety of technologically advanced goods; finally, N_t represents the total number of capital goods invented up to t.

As mentioned just above, the reason why we use the technology expressed in (1), with constant returns to scale in L, H_Y e x_j together, is that it is general enough to allow us, depending on the particular value we attribute to λ and ϕ, to represent different situations (in terms of production function type and inputs contained in it), all equally interesting as far as the aims of this paper are concerned[8].

[7] the reason why we set the restriction $\alpha > \frac{\lambda}{1+\lambda}$ will be clearer later (see also Appendix A).

[8] for example, it is possible to show that when $\lambda = 1$, (1) coincides with the technology used by Grossman and Helpman (chapter 3, p. 45) and borrowed from Dixit and Stiglitz (1977). We will return to this point later.

The representative firm of this sector maximises its own istantaneous profits, taking all the prices as given. Thus, its objective function is:

$$(2)\quad \pi_Y = L^{\phi(1-\lambda)}\cdot(H_Y)^{(1-\phi)(1-\lambda)}\cdot\left[\sum_{j=1}^{N}(x_j)^{\alpha}\right]^{\frac{\lambda}{\alpha}} - \overline{w_t}\cdot L - w\cdot H_Y - \sum_{j=1}^{N} p_j\cdot x_j,$$

where $\overline{w_t}$ is the wage earned (at time t) by one unit of unskilled labour; w is the wage earned by one unit of human capital and p_j is the price of one unit of the j-th variety of capital goods. In (2), Y has been taken as the numeraire ($P_Y = 1$).

From the first order conditions applied to (2), it is possible to derive the (inverse) demand of the downstream sector for the j-th intermediate input (p_j):

$$(3)\quad \frac{\partial \pi_Y}{\partial x_j} = 0 \Rightarrow p_j = \lambda\cdot L^{\phi(1-\lambda)}\cdot(H_Y)^{(1-\phi)(1-\lambda)}\cdot\left[\sum_{j=1}^{N}(x_j)^{\alpha}\right]^{\frac{\lambda}{\alpha}-1}\cdot(x_j)^{\alpha-1}.$$

Under the specific assumption that each firm producing intermediate inputs is so small that a marginal increase in the quantity it produces does not change the quantities produced by its market rivals[9], the demand for the j-th intermediate input exhibits a price elasticity (η) equal to $\frac{1}{1-\alpha}$.

Thus, contrary to the Romer's (1990) model, where the price elasticity of each intermediate input demand is a function of the parameters α and β, representing the exponents of H_Y, L and x[10], in our case α (the only technological parameter defining the above-mentioned elasticity) appears (as an exponent) only in the last term of (1), the one contained in brackets and that represents the contribution to output from the non-competitive sector. As we will see in a moment, α also enters into the definition of the mark-up charged over the marginal cost by the local intermediate monopolists.

• *The intermediate inputs sector*

Each firm produces one (and only one) horizontally differentiated intermediate good. Following Grossman and Helpman (G-H, 1991, chapter 3) we assume that each intermediate (local) monopolist has access to the same (one-to-one) technology, employing skilled labour only:

$$(4)\quad x_j = h_j, \qquad \forall j \in [1;N].$$

For given N (the number of technologically advanced goods invented up to t), (4) implies that the total quantity of human capital allocated at time t to this sector (H_j) is equal to:

$$(4')\quad \sum_{j=1}^{N} x_j = \sum_{j=1}^{N} h_j \equiv H_j.$$

The firm producing the j-th variety, after bearing the expenses related to the purchase of the j-th idea (patent), will maximise, at each point in time, her own instantaneous profit function, subject to the demand constraint (3):

[9] in other words we are assuming that in the intermediate sector there exists no *strategic interaction* among firms, so that $\frac{\partial}{\partial x_j}\left[\sum_{j=1}^{N}(x_j)^{\alpha}\right]^{\frac{\lambda}{\alpha}-1}$ assumes a negligible value.

[10] the aggregate production function used by Romer (1990a) is, indeed, the following: $Y = H_Y^{\alpha}\cdot L^{\beta}\cdot\sum_{i=1}^{\infty}(x_i)^{1-\alpha-\beta}$.

$$(5) \qquad \pi_j = p_j \cdot x_j - w \cdot x_j = \lambda \cdot L^{\phi(1-\lambda)} \cdot (H_Y)^{(1-\phi)(1-\lambda)} \cdot \left[\sum_{j=1}^{N} (x_j)^{\alpha}\right]^{\frac{\lambda}{\alpha}-1} \cdot (x_j)^{\alpha} - w \cdot x_j .$$

Differentiating this expression with respect to x_j, and equating the result to zero, we get:

$$(5') \quad \frac{\partial \pi_j}{\partial x_j} = 0 \Rightarrow \alpha \cdot p_j = w \Rightarrow p_j = \frac{1}{\alpha} \cdot w = p, \qquad \forall j \in [1;N].$$

The result reported in (5') explicitely depends on the assumption that in this sector there exists no *strategic interaction* among firms[11], so that $\frac{\partial}{\partial x_j}\left[\sum_{j=1}^{N}(x_j)^{\alpha}\right]^{\frac{\lambda}{\alpha}-1}$ is approximately equal to zero.

Thus, the mark-up charged over the marginal cost by each intermediate (local) monopolist $(1/\alpha)$ turns out to be (as it should) a function of η (the price elasticity of the demand faced by the j-th intermediate input producer). In fact:

$$\frac{1}{\alpha} = \left(1 - \frac{1}{\eta}\right)^{-1}, \qquad \eta \equiv \frac{1}{1-\alpha} \text{ [12]}.$$

In other words:

> "...*here the parameter* α *is a measure of the degree of competition, since the derived demand curve faced by an intermediate monopolist (i.e., the marginal product schedule) has an elasticity equal to* $1/(1-\alpha)$ *which is increasing in* α". (Aghion e Howitt, 1997, pag.284).

[11] such an assumption is also present in A. Young (1998).

[12] Gali' (1994, 1995, 1996) starts from this very intuitive result in order to study the role mark-ups play in dynamic models with capital accumulation and imperfect competition. Contrary to his approach, however, we assume here that: i) mark-ups, once fixed, do not depend on the demand and/or supply conditions; ii) the accumulable factor is *knowledge* (and not *physical*) capital.

In a symmetric equilibrium (in which both p and x are equal for each j), it is straightforward to derive the following relations:

$$(4'') \quad N \cdot x = H_j \Rightarrow x = \frac{H_j}{N};$$

$$(3') \quad p = \lambda \cdot L^{\phi(1-\lambda)} \cdot (H_Y)^{(1-\phi)(1-\lambda)} \cdot \left[N x^{\alpha}\right]^{\frac{\lambda}{\alpha}-1} \cdot x^{\alpha-1} = \lambda \cdot L^{\phi(1-\lambda)} \cdot (H_Y)^{(1-\phi)(1-\lambda)} \cdot N^{\frac{\lambda-\alpha}{\alpha}} \cdot x^{\lambda-1}.$$

Thus, from (5), the profit of each intermediate firm becomes:

$$(5'') \quad \pi_j = (p-w) \cdot x = (1-\alpha) \cdot \lambda \cdot L^{\phi(1-\lambda)} \cdot (H_Y)^{(1-\phi)(1-\lambda)} \cdot H_j^{\lambda} \cdot N^{\frac{\lambda-\alpha(1+\lambda)}{\alpha}} = \pi, \quad \forall j \in [1;N].$$

In synthesis, in the perfectly symmetric case, each firm producing technologically advanced goods will decide at time t to produce the same quantity of output (x), to sell it at the same price (p), getting, at the end, the same instantaneous profit rate (π). This result follows from the symmetry of the production technology (1).

It is also worth noting that π will be decreasing in N (the number of varieties existing at time t) if and only if $\alpha > \frac{\lambda}{1+\lambda}$. This explains the restriction on α we have explicitely introduced (see (1)).

- *The research sector.*

Producing the generic j-th variety of capital goods entails the purchase (at no transation cost) of a specific blueprint (the j-th one) from the competitive research sector, characterised by the following technology[13]:

$$(6)\quad \dot{N} = G(N, H_N) = \frac{1}{\eta} \cdot N \cdot H_N$$

where $\frac{1}{\eta}$ $(\eta > 0)$ is the productivity parameter of the human capital employed in the sector (H_N) and N is the number of horizontally differentiated intermediate goods existing at time t. Since this sector is competitive, the price of the j-th blueprint will be equal, at time t, to the discounted value of the profits that can be made, from t onwards, by the j-th intermediate firm[14]. In other words, it will be the case that:

$$(7)\quad P_{Nt} = \int_t^{\infty} \pi_\tau \cdot e^{-r(\tau-t)} d\tau = \lambda(1-\alpha) L^{\phi(1-\lambda)} \int_t^{\infty} (H_{Y\tau})^{(1-\phi)(1-\lambda)} \cdot (H_{j\tau})^{\lambda} \cdot (N_\tau)^{\frac{\lambda-\alpha(1+\lambda)}{\alpha}} \cdot e^{-r(\tau-t)} d\tau, \ \tau > t.$$

In this expression, P_{Nt} is the price (at time t) of the generic j-th blueprint (the one that allows to produce the j-th variety of capital goods), π is the profit of the j-th intermediate firm and r is the exogenous interest rate.

From (6), it is clear that producing a new blueprint requires an amount of human capital equal to $\frac{\eta}{N}$, for a total cost of $\frac{\eta}{N} \cdot w$. Consequently, the static free-entry condition can be written as follows:

$$(8)\quad P_N = \frac{\eta}{N} \cdot w \Rightarrow w = \frac{P_N \cdot N}{\eta},$$

[13] the production function of new "ideas" (blueprints) reported in (6) is standard in the deterministic innovation-driven endogenous growth literature. In particular, it coincides with the one used by Romer (1990a, p. S83) and Grossman and Helpman (1991, chapter 3, p. 58) in their path-breaking papers. According to Keely and Quah (1998), it also displays two features which are partly corroborated by empirical evidence: 1) the (positive) correlation between research input (H_N) and output (patents); 2) the cumulative nature of research (such that new ideas or discoveries build upon earlier ones).

[14] indeed, there exists a one-to-one relationship among the number of blueprints (produced in the research sector), the number of firms operating in the intermediate sector and the number of capital goods.

where P_N assumes the value indicated in (7) and w is the wage rate accruing to one unit of human capital.

In words, (8) simply states that the entry of new firms into the sector will continue until the price that one can obtain from the sale of an additional blueprint (P_N) equals the production marginal cost of the blueprint itself $\left(\frac{\eta}{N} \cdot w\right)$. The description of the preferences closes the model.

• *Consumers*

In this economy, population (made up of skilled and unskilled workers) is stationary[15] and there exists full employment. In such a context, an infinitely-lived agent solves the following dynamic problem:

$$(9)\quad \begin{cases} \underset{\{Y\}_{t=0}^{\infty}}{Max}\, U_0 = \int_0^{\infty} e^{-\rho t} \cdot \log(Y_t) dt \\ s.t.: \\ \dot{W}_t = w_t + r_t \cdot W_t - Y_t \\ \lim_{t \to \infty} \lambda_t \cdot W_t = 0 \end{cases}$$

The symbols have the following meaning: U_0 is the intertemporal utility function; $\log(Y_t)$ is the instantaneous utility function; $\rho (> 0)$ is the individual discount factor; λ_t is the so-called co-state variable and W, w and r are respectively total wealth of the representative agent, his/her wage and the (exogenous) interest rate at time t.

Applying the *Maximum Principle* to (9) yields:

$$(10)\quad \gamma_Y = \frac{\dot{Y}_t}{Y_t} = r_t - \rho.$$

[15] there is no population growth.

In steady-state, with r exogeneously given, the growth rate will be constant.

• *The equilibrium in the Human Capital market and the steady-state.*

In order to determine the optimal allocation of the (fixed) total stock of human capital to the three sectors using this resource (the ones producing respectively the final good, intermediates and research), in what follows we shall employ the same methodology proposed by Romer (1990a) and consisting in equalising the wage rates earned by one unit of human capital in each of the above-mentioned sectors. To do so, we have just to imagine that human capital is an homogeneous input within this economy and, as such, it is compensated by an unique wage rate[16].

If this is the case, then the following three conditions must simultaneously be checked:

(11) $H = H_{jt} + H_{Nt} + H_{Yt}, \qquad \forall t;$

(12) $w_j = w_Y;$

(13) $w_j = w_N.$

(11) is a simple resource constraint, in accordance to which, at any point in time, the sum of the human capital stocks employed in each sector must exactly be equal to the fixed supply (H).

The second condition states that the wage earned by one unit of human capital in the capital goods sector (w_j) must be equal to the wage earned by the same unit of human capital in the case this one were to be used to produce the consumer good (w_Y).

Finally, (13) states the same principle expressed in (12), but with reference to the intermediate and research sectors. Thus, (12) and (13) together say that, from the viewpoint of the private return, it should be indifferent for the holder of one unit of human capital to put this resource into use in one or another of the three sectors composing the economy (in this sense, (12) and (13) are *no-arbitrage conditions*).

The simultaneous application of (11), (12) and (13) yields the following equilibrium values for the relevant variables of the model:

(14) $$r = \frac{\lambda^2(1-\alpha)^2 \cdot H + A\rho\eta}{\eta B} = \frac{\lambda^2(1-\alpha)^2 \cdot H + A\rho\eta}{\eta\alpha[\phi(\lambda-1)+1]};$$

(15) $$H_N = \frac{1}{B}\{\alpha\lambda(1-\alpha)\cdot H - \alpha\eta\rho[\alpha\lambda + (1-\phi)(1-\lambda)]\};$$

(16) $$H_j = \frac{\alpha\lambda[B - \alpha\lambda(1-\alpha)]}{[\alpha\lambda + (1-\phi)(1-\lambda)]\cdot B}\cdot H + \frac{\alpha^2\lambda\eta\rho}{B};$$

(17) $$H_Y = \frac{(1-\phi)(1-\lambda)}{\alpha\lambda}\cdot H_j = \frac{(1-\phi)(1-\lambda)[B - \alpha\lambda(1-\alpha)]}{[\alpha\lambda + (1-\phi)(1-\lambda)]\cdot B}\cdot H + \frac{\alpha\eta\rho(1-\phi)(1-\lambda)}{B};$$

(18) $$\gamma_Y = \frac{\dot{Y}}{Y} = r - \rho = \frac{\lambda(1-\alpha)\{\lambda(1-\alpha)\cdot H - \eta\rho[\alpha\lambda + (1-\phi)(1-\lambda)]\}}{\eta\alpha[\phi(\lambda-1)+1]};$$

(19) $$\frac{\dot{N}}{N} = \gamma_N = \frac{1}{\eta}\cdot H_N = \frac{1}{\eta B}\{\alpha\lambda(1-\alpha)H - \alpha\eta\rho[\alpha\lambda + (1-\phi)(1-\lambda)]\};$$

(20) $$A \equiv \lambda[\alpha\lambda(\alpha - 2 + \phi) + \lambda(1-\phi) + \alpha - 1 + \phi] + \alpha(1-\phi);$$

(21) $$B \equiv \{A + \lambda(1-\alpha)\cdot[\alpha\lambda + (1-\phi)(1-\lambda)]\} = \alpha[\phi(\lambda-1)+1].$$

(See Appendix A for analytical details).

Thus, the growth rate of this economy (γ_Y) is a function both of the (technological and preference) parameters of the model $(\lambda, \eta, \rho, \phi)$ and α (the inverse of the mark-up charged over the marginal cost by the firms producing technologically advanced goods). It also positively depends on H (the total stock of human capital existing in the

[16] in other words we assume that the same skills actually being used to produce, say, technologically advanced goods can be put into use to produce, with the same productivity level, also knowledge and an homogeneous final good.

economy)[17]. In this sense, our model (as all the R&D-based approaches) supports the Nelson and Phelps' (1966) idea, according to which it is the *stock* (and not the *accumulation rate*) of human capital to sustain growth in the very long run[18]. In other words, the international differences in per-capita income growth rates are mainly due to differences in the human capital stocks among countries and, as a consequence, to their different capabilities to generate technical progress[19].

3. Technology, (fixed supply) human capital and the interplay between market power and growth.

In this section, we analyse the way both *technology* and (what we call) *inter-sectoral competition for human capital* affect the *mark-up/growth relationship.* To do so, we go back to (1) and study the following cases:

a) for $\lambda=1$, (1) implies: $Y_t=\left[\sum_{j=1}^{N_t}(x_{jt})^{\alpha}\right]^{\frac{1}{\alpha}}$;

[17] Jones (1995a) observes that, in most OECD countries, while the number of engineers and scientists engaged in the R&D activity has risen dramatically over the past half century, per-capita income growth rates have either remained roughly constant or even declined. On these grounds, Jones (1995b) rejects the R&D-based growth models exhibiting scale effects. According to Aghion and Howitt (1998), however, the increase in R&D investment has not been so high as data seem to suggest and consequently the scale effects predicted by some endogenous growth models are not to be considered as unreasonable as initially thought. Recent attempts to model the growth process of a country as not depending (or asymptotically not depending) on the so-called scale effects include A. Young (1998), Peretto and Smulders (1998); Jones (1995a;1997) and Aghion and Howitt (1998, pp.407-415). In the last three models, the steady-state growth rate of the economy turns out to depend positively upon the population growth rate.

[18] the intuition is that a higher number of educated workers may make it easier for a country to adopt or implement new technologies.

[19] recently, the influential paper by Benhabib and Spiegel (1994) has shed light on the empirical validity of the Nelson and Phelps' (1966) hypothesis, providing further support to the *innovation-driven* growth literature.

b1) for $\lambda=\alpha$ and $\phi=1$: $Y_t=L^{1-\alpha}\cdot\sum_{j=1}^{N_t}(x_{jt})^{\alpha}$;

b2) for $\lambda=\alpha$ and $\phi=0$: $Y_t=(H_{Yt})^{1-\alpha}\cdot\sum_{j=1}^{N_t}(x_{jt})^{\alpha}$;

c) for $\lambda=0$ and $0<\phi<1$: $Y_t=L^{\phi}\cdot(H_{Yt})^{1-\phi}$.

The cases where we identify a low level of competition among sectors for the acquisition of human capital are the cases sub a) and sub b1). In the first one (sub a), the final output technology is of the CES type, human capital is directly employed in the intermediate and research sectors, and the model is the G-H's one (1991, chapter 3). In the b1) case, the technology currently used in the downstream sector is Cobb-Douglas (with unskilled labour and intermediate goods as inputs) and, again, human capital is exclusively used to produce technologically advanced goods and knowledge.

On the other side, in the b2) case there exists the maximum level of competition for human capital, in the sense that now this input enters each sector production function. This is also true for case sub c), but this case is less interesting than the preceding ones (and, as such, will not be studied) for the following two reasons: 1) first of all, because in this context the downstream sector does not employ intermediate inputs, for which there is now no need (consequently, there is no need also for industrial research, whose purpose is to patent new ideas for new capital goods); 2) secondly, because in equilibrium (when a constant stock of human capital is allocated to each sector) the aggregate growth rate of this economy turns out to be exactly equal to zero, as there is no knowledge accumulation[20] (the real "engine" of growth).

Besides the cases we have just mentioned, the more general model we proposed in the last section is also able to embed, as a particular case, the original work by Romer (1990a) - (case (d) from now on). For this to happen, it is sufficient to set (in (1)) $\lambda=\alpha$, $\phi=0$ and to

[20] in the form of a continuous expansion in the range of existing intermediate inputs.

interpret the capital employed by the intermediate (local) monopolists as physical capital, rather than human capital (so that now one unit of physical capital allows to produce exactly one unit of whatever capital goods variety). Under these assumptions, the equilibrium conditions characterising the human capital market become:

i) $H=H_Y+H_N$
ii) $w_Y=w_N$.

Finally, following a procedure similar to the one we show in detail in Appendix A, the steady state values of r, H_N, H_Y, γ_Y and γ_N can be respectively reexpressed in the following way:

$$(22)\quad r=\left(\frac{1}{\eta}H+\rho\right)\left(\frac{\alpha}{1+\alpha}\right);$$

$$(23)\quad H_N=\left(\frac{1}{1+\alpha}\right)(\alpha H-\eta\rho);$$

$$(24)\quad H_Y=\frac{1}{\alpha}r\eta=\left(\frac{1}{1+\alpha}\right)(H+\eta\rho);$$

$$(25)\quad \gamma_Y=\frac{\frac{\alpha}{\eta}H-\rho}{1+\alpha};$$

$$(26)\quad \gamma_N=\frac{\dot{N}}{N}=\frac{1}{\eta(1+\alpha)}(\alpha H-\eta\rho).$$

Before proceeding with Proposition 1, it is worth noting that:

Observation 1:

If, in (1), we set $\lambda=1$, we get the same steady-state innovation (γ_N) and growth (γ_Y) rates found by G-H (1991, chapter 3), even using a methodology different from theirs.

Indeed, with $\lambda=1$, (18) and (19) become respectively:

$$(18')\quad \gamma_Y=(1-\alpha)\left[\frac{(1-\alpha)}{\eta\alpha}H-\rho\right]=\left(\frac{1-\alpha}{\alpha}\right)\gamma_N.$$

$$(19')\quad \gamma_N=\left(\frac{1-\alpha}{\eta}\right)H-\alpha\rho.$$

Proposition 1:

In a model of market power and growth "à la Romer/G-H/Nelson-Phelps", the existence of a positive relationship between mark-up ($\beta\equiv 1/\alpha$) and aggregate growth (γ_Y)(at least in any relevant range of β), is due to the explicit hypothesis that the capital goods (or intermediate) sector employs human capital.

In order to prove this, in Appendix B, we analyse the behaviour of γ_Y (as a function of β) in each of the cases labeled rispectively as a), b1), b2) and d) (Romer's model). In the first three situations (a, b1 and b2), the capital goods sector employs human capital and the relationship between monopoly power and growth is (at least in some interval of β) positive. On the contrary, in case sub d) the intermediate sector uses physical (and not human) capital and, as it is clear from Figure 4, $\gamma_Y(\beta)$ is monotonically decreasing.

The intuition for this result is quite simple: when the mark-up rate $(1/\alpha)$ goes to infinite (i.e., $\alpha\to 0$), the total quantity of capital goods which is produced in equilibrium (Nx) declines to zero and the same happens to the intermediate sector demand for human capital (note, indeed, that, from (4''), $H_j=Nx$). Consequently, a greater number of skilled workers may be allocated to the research sector (that drives growth).

This causal relationship between monopoly power and economic development is certainly present in cases (a) - the G-H's model - and (b1), where the *inter-sectoral competition for human capital* concerns exclusively the capital goods and research sectors. Indeed, comparing these two cases, we get the following

Result 1

ceteris paribus, the type of technology used in the homogeneous final output sector affects the relationship between γ_Y and β. On the one hand, for β going to infinite,when the production function is CES (case (a)), such a relationship approaches a positively sloping straight line; on the other, when technology is Cobb-Douglas (case (b1)), the same (positive) relationship assumes a concave shape.

Contrary to these two situations, it is possible to show that, for given parameter values[21], in the (b2) case (where human capital is employed in each economic sector), there exists an (exogenous) optimal β (β^*), which maximises the aggregate growth rate. For values of β greater than β^*, the relationship between mark-up and growth is always negative, since further increases in β force the downstream producers to substitute (given their technology) capital goods with skilled workers. Consequently, the stock of human capital which may be employed in the *growth-driving sector* (research) goes down[22]. For values of β less than β^*, instead, the relationship between this variable and γ_Y may be positive or negative depending on the absolute value of the mark-up term (β) - (see Appendix C). In brief, we have the following:

Result 2

for given technology (Cobb/Douglas production function), whether or not the fixed supply relevant input (human capital) is employed for producing the consumer good can dramatically change the shape of the relationship between γ_Y and β. We get this result just

[21] in particular, $H > 3\eta\rho$ (see Bucci (1998)).

[22] a similar effect is also present in the Romer's model. Note, indeed, that in both cases (sub d) and sub b2), in Appendix B), $\lim_{\beta \to \infty} \gamma_Y(\beta) = -\rho$.

comparing the behaviour of $\gamma_Y(\beta)$ in the two cases labeled respectively as (b1) and (b2).

Putting together Result 1 and 2, we can conclude that in a context of horizontal and deterministic product innovation, the nexus between the (exogenous) monopoly power enjoyed by the local intermediate producers and the aggregate output growth rate is not robust at all, depending on the type of production function currently employed by the consumer good firms and on the kind of inputs entering the technology of the downstream and capital goods sectors (physical/human capital; skilled/unskilled labour).

The next step consists in showing that these two elements (technology, on one hand and the inter-sectoral competition for the fixed supply relevant input, on the other) can also affect the equilibrium value of the aggregate economic growth rate.

3.1 Technology, (fixed supply) human capital and growth. Some policy implications.

In this section, we show that the equilibrium growth rate of the economy also depends both on the type of production function employed by the consumer good producers and the kind of inputs entering in it. As far as the relationship between the inter-sectoral allocation of human capital and growth is concerned, it is possible to note that:

Result 3

for given technology, whether or not human capital is employed as an input in the production of the homogeneous final good, affects the overall growth rate of the economy.

Indeed, comparing the aggregate growth rates (γ_Y) prevailing in the cases (b1) and (b2)[23], we notice that $\gamma_Y(b2)$ is always less than $\gamma_Y(b1)$. In other words, employing the relevant fixed supply input (human capital) in the downstream sector implies a deterioration of the overall economic performance.

Thus, such a result supports (in a peculiar sense) one of the main conclusions of Lucas (1993), according to which cross-country differences in per capita income growth rates may well depend on how skilled workers are *allocated* to different sectors. This effect is known in the literature as the *"Lucas effect"* (Aghion and Howitt, 1998) and is very often invoked in order to account for the remarkable growth performances of some newly industrialised countries (like Hong Kong, Korea, Singapore and Taiwan), that have recently been particularly able to switch workers from traditional (or less sophisticated) productions to more technologically advanced ones or even research. However, in our case, contrary to Lucas (1993)[24], the inter-sectoral allocation of human capital matters for growth because it is potentially able to increase the steady-state number of researchers, in a context in which the total stock of skilled labour (H) is fixed and the true engine of growth is indeed represented by the continuous creation, through the R&D investment, of new innovation opportunities.

Finally, as far as the relationship between technology and growth is concerned, we have the following

Result 4:

ceteris paribus, the type of production function currently used to get the homogeneous consumer good significantly affects the equilibrium economic growth rate. In particular, it is possible to show that this is higher whenever the final output technology is CES (and does not employ human capital).

[23] these are, in fact, the cases in which, ceteris paribus, what changes is exclusively the nature (skilled/unskilled) of labour being used in the final output sector.
[24] where learning by doing considerations play the relevant role.

This result follows immediately from the comparison between the equilibrium growth rates that one obtains in the cases (a) and (b1) respectively. From such a comparison, indeed, we get that $\gamma_Y(a)$ is always greater than $\gamma_Y(b1)$.

In synthesis, and taking into consideration all the results we have stated till now, the economy reaches the highest possible growth rate when the *competition* for human capital is confined to the innovation-leading sectors (the intermediate and research ones) <u>and</u> the consumer good sector technology is CES (these two characteristics are both present in the G-H's model of deterministic innovation and growth (1991, chapter 3)). For β sufficiently large[25], such a growth rate is, in effect, higher than that we obtain in the Romer/Barro/Sala-y-Martin approach (1995, chapter 6), where human capital is used by the downstream and research sectors and the technology of the first of the two just mentioned sectors is Cobb-Douglas[26].

The most relevant policy implication stemming from these conclusions has to do with the fact that, for given technologies (Cobb-Douglas/CES, for instance) the inter-sectoral allocation of human capital may have important growth effects. In the endogenous innovation literature, human capital is, indeed, generally assumed not to grow over time and to be equally productive in manufacturing and research. In such a contest, a growth-maximising policy-maker may reach his/her objective simply channeling more resources to the innovating sectors (capital goods and research). In addition to this, in the completely deterministic framework of innovation, what really seems to matter for growth is not only the total stock of human capital, but also, and more importantly, the way (i.e., to which sectors) such an available stock is allocated. In this sense, an education policy oriented to increase the polyvalence of workers and their mobility from manufacturing to research may well be growth-enhancing.

[25] in particular, $\beta \equiv \frac{1}{\alpha} > 1,802$.

[26] this derives confronting (18) and (25), with $\lambda = 1$ and $\alpha \equiv \frac{1}{\beta}$.

4. Conclusions

One of the main findings of New Growth Theory is to consider technological change not simply as a *"manna from heaven"* (Fagerberg, 1994), but, on the contrary, as the outcome of some activity (research and development) intentionally conducted by private, profit seeking agents.

In order to make formally explicit the positive relationship between the aggregate economic growth rate (γ) and the intensity of innovative effort, in the early 1990s several theoretical models (the so-called R&D-based growth models) have been published. All of these share the common feature that technology is a non-rival and partially excludable good, so that it is a powerful source of positive externalities. In such a framework, it is not surprising that the only economic force able to stimulate private agents to innovate be represented by some measure of (ex-post) monopoly power accruing to the potential innovator, if successful. However, the idea to consider the existence of some possible positive linkage among market power, innovation and growth is not unambiguously present in the *deterministic* innovation-driven growth models.

In order to formally show this result, in the present paper we have built a more general model of deterministic horizontal innovation and growth, able to encompass, as particular cases, also the Romer (1990a) and Grossman and Helpman (1991, chapter 3) approaches. What our analysis shows is that, when innovation is not vertical and stochastic, a positive relationship between market power and growth may stem only under particular assumptions on the kind of technology and inputs currently employed by each economic sector. In other words, depending on the way the structure of the economy is modelled (in terms of both functional forms and their arguments), increasing market power may or may not stimulate growth. In policy terms, this implies the prominence for a growth-maximising policy maker to set up an education system that makes workers' intersectoral mobility possible and easier.

Of course, these results strongly depends on the hypothesis (common to all the innovation-based growth models) that human capital is in fixed supply. It could be interesting from our viewpoint to analyse how the monopoly power-growth relationship and the equilibrium growth rate in itself change when we allow an economic system (similar to the one we have considered in this paper) to accumulate over time not only "ideas" (in the form of new, horizontally differentiated intermediate goods), but also human capital, through a separate education sector.

Appendix A

In this Appendix, we derive the set of equations (14)-(21) reported in the main text.

Using (1), (5') and (3'), and the symmetric equilibrium hypothesis[27], from (12) we get:

$$(27)\quad H_Y = \frac{(1-\phi)(1-\lambda)}{\alpha\lambda} \cdot H_j.$$

Substituting (27) into (11) yields:

$$(28)\quad H_j = \left[\frac{\alpha\lambda}{\alpha\lambda + (1-\phi)(1-\lambda)}\right] \cdot (H - H_N).$$

Consequently, (27) can be rewritten as:

$$(27')\quad H_Y = \frac{(1-\phi)(1-\lambda)}{\alpha\lambda + (1-\phi)(1-\lambda)} \cdot (H - H_N).$$

[27] such that $x_j = \frac{H_j}{N} = x, \quad \forall\ j \in [1; N]$.

In order to find the wage paid to one unit of human capital employed in the research sector (w_N), it is worth noting, first of all, that in steady-state H_N, H_j and H_Y are constant[28]. Thus, (7) becomes:

$$(7')\quad P_{Nt} = \lambda\cdot(1-\alpha)\cdot L^{\phi(1-\lambda)}\cdot(H_Y)^{(1-\phi)(1-\lambda)}\cdot(H_j)^{\lambda}\cdot(N_t)^{\frac{\lambda-\alpha(1+\lambda)}{\alpha}}\cdot\int_t^{\infty} e^{\left[\left(\frac{\lambda-\alpha(1+\lambda)}{\eta\alpha}\right)H_N-r\right](\tau-t)}d\tau=$$

$$= \lambda\cdot(1-\alpha)\cdot L^{\phi(1-\lambda)}\cdot(H_Y)^{(1-\phi)(1-\lambda)}\cdot(H_j)^{\lambda}\cdot(N_t)^{\frac{\lambda-\alpha(1+\lambda)}{\alpha}}\cdot\frac{\eta\alpha}{[-\lambda+\alpha(1+\lambda)]\cdot H_N+r\eta\alpha}.$$

To write (7') in its final form we have considered (6) in the main text, stating that $\frac{\dot{N}_t}{N_t}=\frac{1}{\eta}H_{Nt}$. This implies that $N_t=N_0\cdot e^{\frac{1}{\eta}H_N t}$, or $N_\tau=N_t\cdot e^{\frac{1}{\eta}H_N(\tau-t)}$ and, thus, $(N_\tau)^{\frac{\lambda-\alpha(1+\lambda)}{\alpha}}=(N_t)^{\frac{\lambda-\alpha(1+\lambda)}{\alpha}}\cdot e^{\left[\frac{\lambda-\alpha(1+\lambda)}{\eta\alpha}\right]H_N(\tau-t)}$. In addition to this, we have also assumed:

a) r constant and strictly positive[29];

b) $\left[-\left(\frac{\lambda-\alpha(1+\lambda)}{\eta\alpha}\right)H_N+r\right]>0.$

The expression in brackets, with r and H_N strictly positive, will be positive for $\alpha>\frac{\lambda}{1+\lambda}$. Note that when $\alpha>\frac{\lambda}{1+\lambda}$, both P_{Nt} (the price of the generic j-th blueprint at t) and π_j (the profit, at t, of the generic j-th producer of capital goods) turn out to be decreasing functions of N_t (the number of varieties of horizontally differentiated intermediate goods existing at t). This means that an increase in N, determining a proportional increase in the level of competition within the intermediate inputs sector, contributes to reduce (as we would expect) the price and the profit pertaining to the same j-th capital input. Such effect is reflected in a sufficiently high α (the inverse of the mark-up

[28] see (6), (28) and (27').

[29] this is so in all the cases we consider throughout the entire paper (see Appendix B).

term charged by the local intermediate monopolists over their marginal cost).

Given P_N, it is now possible to compute the wage rate in the research sector (w_N):

$$(8')\quad w_N=w=\frac{P_N\cdot N}{\eta}=\lambda(1-\alpha)\cdot L^{\phi(1-\lambda)}\cdot(H_Y)^{(1-\phi)(1-\lambda)}\cdot(H_j)^{\lambda}\cdot(N)^{\frac{\lambda(1-\alpha)}{\alpha}}\cdot\frac{\alpha}{[-\lambda+\alpha(1+\lambda)]\cdot H_N+r\eta\alpha}.$$

Equating, from (13), w_j and w_N yields:

$$(28')\quad H_j=\frac{[-\lambda+\alpha(1+\lambda)]\cdot H_N+r\eta\alpha}{(1-\alpha)}.$$

Putting together (28) and (28'), we get the following expression for H_N:

$$(29)\quad H_N=\frac{\alpha\{\lambda(1-\alpha)H-r\eta[\alpha\lambda+(1-\phi)(1-\lambda)]\}}{A},$$

where $A\equiv\lambda[\alpha\lambda(\alpha-2+\phi)+\lambda(1-\phi)+\alpha-1+\phi]+\alpha(1-\phi)$. Consequently,

$$(28'')\quad H_j=\frac{\alpha[-\lambda+\alpha(1+\lambda)]\cdot\{\lambda(1-\alpha)H-r\eta[\alpha\lambda+(1-\phi)(1-\lambda)]\}}{(1-\alpha)A}+\frac{r\eta\alpha}{(1-\alpha)}.$$

To determine the equilibrium interest rate, we note that:

- $r=\gamma_Y+\rho$ (from (10);
- $\gamma_Y=\left[\frac{\lambda(1-\alpha)}{\alpha}\right]\cdot\frac{\dot{N}}{N}=\left[\frac{\lambda(1-\alpha)}{\eta\alpha}\right]\cdot H_N$ (from (1) and with L, H_j and H_Y constant).

From these relations, and using (29), we can write r as reported in the main text:

$$(14)\quad r=\frac{\lambda^2(1-\alpha)^2\cdot H+A\rho\eta}{\eta B}=\frac{\lambda^2(1-\alpha)^2\cdot H+A\rho\eta}{\eta\alpha[\phi(\lambda-1)+1]},$$

where $B\equiv\{A+\lambda(1-\alpha)\cdot[\alpha\lambda+(1-\phi)(1-\lambda)]\}=\alpha[\phi(\lambda-1)+1]$.

Finally, from (14), we derive all the other relevant variables of the model:

$$(15)\quad H_N=\frac{1}{B}\{\alpha\lambda(1-\alpha)\cdot H-\alpha\eta\rho[\alpha\lambda+(1-\phi)(1-\lambda)]\};$$

$$(16)\quad H_j=\frac{\alpha\lambda[B-\alpha\lambda(1-\alpha)]}{[\alpha\lambda+(1-\phi)(1-\lambda)]\cdot B}\cdot H+\frac{\alpha^2\lambda\eta\rho}{B};$$

$$(17)\quad H_Y=\frac{(1-\phi)(1-\lambda)}{\alpha\lambda}\cdot H_j=\frac{(1-\phi)(1-\lambda)[B-\alpha\lambda(1-\alpha)]}{[\alpha\lambda+(1-\phi)(1-\lambda)]\cdot B}\cdot H+\frac{\alpha\eta\rho(1-\phi)(1-\lambda)}{B};$$

$$(18)\quad \gamma_Y=\frac{\dot{Y}}{Y}=r-\rho=\frac{\lambda(1-\alpha)\{\lambda(1-\alpha)\cdot H-\eta\rho[\alpha\lambda+(1-\phi)(1-\lambda)]\}}{\eta\alpha[\phi(\lambda-1)+1]};$$

$$(19)\quad \frac{\dot{N}}{N}=\gamma_N=\frac{1}{\eta}\cdot H_N=\frac{1}{\eta B}\{\alpha\lambda(1-\alpha)H-\alpha\eta\rho[\alpha\lambda+(1-\phi)(1-\lambda)]\}.$$

Appendix B

In this Appendix, we analyse the behaviour of the steady-state growth rate of the economy as a function of the mark-up term. We also compute the value of the main variables of the model (listed from (14) to (21) in the text) for each of the cases labeled as (a), (b1), (b2) and (d). The simulations presented assume $H>3\eta\rho$ and, in particular, to make the pictures clearer, H=5000, $\eta=2000$ and $\rho=0.8$.

Case (a)

When $\lambda=1$ (Grossman and Helpman's model (1991, chapter 3)), the technologies in use in each economic sector are as follows:

- $Y_t=\left[\sum_{j=1}^{N_t}(x_{jt})^\alpha\right]^{\frac{1}{\alpha}}$ (final output);
- $x_{jt}=h_{jt},\ \forall j\in[1;N_t]$ (capital goods)
- $\dot{N}_t=\frac{1}{\eta}\cdot N_t\cdot H_{Nt}$ (research)

In equilibrium, we have:

$$A=\alpha^2;\quad B=\alpha;\quad r=\frac{(1-\alpha)^2}{\eta\alpha}H+\alpha\rho>0;\quad H_j=\alpha(H+\eta\rho);$$

$$H_Y=0;\quad H_N=(1-\alpha)H-\alpha\eta\rho;\quad \gamma_N=\frac{\dot{N}}{N}=\frac{1}{\eta}H_N=\left(\frac{1-\alpha}{\eta}\right)H-\alpha\rho;$$

$$\gamma_Y=(1-\alpha)\cdot\left[\frac{(1-\alpha)}{\eta\alpha}H-\rho\right]=\left(\frac{1-\alpha}{\alpha}\right)\cdot\frac{\dot{N}}{N}=\left(\frac{\beta-1}{\beta}\right)\left[\left(\frac{\beta-1}{\eta}\right)H-\rho\right],\ \beta\equiv\frac{1}{\alpha}>1.$$

In this case, $\gamma_Y(\beta)$ behaves as follows:

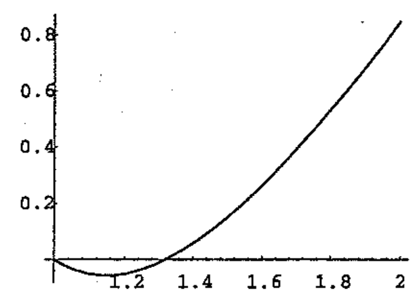

Figure 1

Case (b1)

When $\lambda = \alpha$ and $\phi = 1$, the production functions become:

- $Y_t = L^{1-\alpha} \cdot \sum_{j=1}^{N_t} (x_{jt})^{\alpha}$ (final output)
- $x_{jt} = h_{jt}, \ \forall j \in [1; N_t]$ (capital goods)
- $\dot{N}_t = \frac{1}{\eta} \cdot N_t \cdot H_{Nt}$ (research)

In steady-state:

$$A = \alpha^2(\alpha^2 - \alpha + 1); \qquad B = \alpha^2; \qquad r = \frac{(1-\alpha)^2}{\eta} H + \rho(\alpha^2 - \alpha + 1) > 0;$$

$$H_j = \alpha(H + \eta\rho); \qquad H_Y = 0; \qquad H_N = (1-\alpha)H - \alpha\eta\rho;$$

$$\gamma_N = \frac{\dot{N}}{N} = \frac{1}{\eta} H_N = \left(\frac{1-\alpha}{\eta}\right) H - \alpha\rho;$$

$$\gamma_Y = (1-\alpha) \cdot \left[\frac{(1-\alpha)}{\eta} H - \alpha\rho\right] = (1-\alpha) \cdot \frac{\dot{N}}{N} = \frac{(\beta-1)^2 H - \eta\rho(\beta-1)}{\eta\beta^2}, \quad \beta \equiv \frac{1}{\alpha} > 1.$$

Note that in this case H_j, H_Y, H_N e γ_N coincide perfectly with the respective values found in case (a). Consequently, the differences in γ_Y, *ceteris paribus*, are to be imputed to the two different technologies used in the final output sector (Cobb Douglas versus CES)[30].

The relationship between aggregate growth and monopoly power is now the following:

[30] for a further comment on this point, see Bucci (1998), p.15.

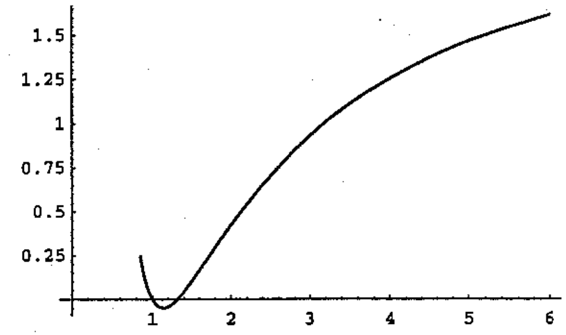

Figure 2

Case (b2)

If we set $\lambda = \alpha$ and $\phi = 0$, then the technologies used in the final output, intermediate and research sectors are respectively:

- $Y_t = (H_{Yt})^{1-\alpha} \cdot \sum_{j=1}^{N_t} (x_{jt})^{\alpha}$ (final output)
- $x_{jt} = h_{jt}, \forall j \in [1; N_t]$ (capital goods)
- $\dot{N}_t = \frac{1}{\eta} \cdot N_t \cdot H_{Nt}$ (research)

In steady-state:

$$A = \alpha^2(\alpha^2 - 2\alpha + 2); \qquad B = \alpha;$$

$$r = \frac{\alpha(1-\alpha)^2}{\eta} H + \alpha\rho(\alpha^2 - 2\alpha + 2) > 0; \qquad H_j = \alpha^2(H + \eta\rho);$$

$$H_Y = (1-\alpha)(H + \eta\rho); \quad H_N = \alpha(1-\alpha)H - \eta\rho(\alpha^2 - \alpha + 1);$$

$$\gamma_N = \frac{\dot{N}}{N} = \frac{1}{\eta} H_N = \frac{\alpha(1-\alpha)}{\eta} H - \rho(\alpha^2 - \alpha + 1);$$

$$\gamma_Y = \frac{\alpha(1-\alpha)^2}{\eta} H + \rho(\alpha^3 - 2\alpha^2 + 2\alpha - 1) = \frac{-\eta\rho\beta^3 + (H + 2\eta\rho)\beta^2 - 2(H + \eta\rho)\beta + (H + \eta\rho)}{\eta\beta^3},$$

$$\beta \equiv \frac{1}{\alpha} > 1 .$$

The last equation presents the following graphical behaviour:

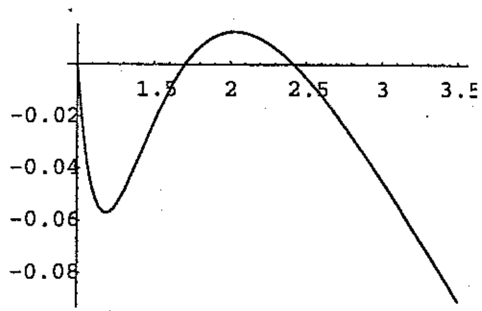

Figure 3

Case (d)

Let us assume that, in (1), $\lambda = \alpha$ and $\phi = 0$. In addition, let us interpret the capital employed by the intermediate local monopolists as physical (rather than human) capital (so that (4) now reads: one unit of physical capital allows to produce exactly one unit of whatever variety of technologically advanced goods). Under these assumptions, we get the Romer's 1990 model, in its semplified version given by Barro and Sala-y-Martin (1995, chapter 6, pp.226-230). In such case, the production functions are:

- $Y_t = (H_{Yt})^{1-\alpha} \cdot \sum_{j=1}^{N_t} (x_{jt})^{\alpha}$ (final output)
- $x_{jt} = k_{jt},\ \forall j \in [1; N_t]$ (capital goods)
- $\dot{N}_t = \frac{1}{\eta} \cdot N_t \cdot H_{Nt}$ (research)

For r, H_j, H_Y, H_N, γ_N and γ_Y, we now have:

$$r = \left(\frac{1}{\eta} H + \rho\right)\left(\frac{\alpha}{1+\alpha}\right) > 0; \qquad H_j = 0; \qquad H_Y = \frac{1}{\alpha} r\eta = \left(\frac{1}{1+\alpha}\right)(H + \eta\rho);$$

$$H_N = \left(\frac{1}{1+\alpha}\right)(\alpha H - \eta\rho); \qquad \frac{\dot{N}}{N} = \gamma_N = \frac{1}{\eta} H_N = \frac{1}{\eta(1+\alpha)}(\alpha H - \eta\rho);$$

$$\gamma_Y = \frac{\frac{\alpha}{\eta} H - \rho}{1+\alpha} = \frac{H - \eta\rho\beta}{\eta(\beta+1)}, \qquad \beta \equiv \frac{1}{\alpha} > 1.$$

The behaviour of $\gamma_Y(\beta)$ is in this case as follows:

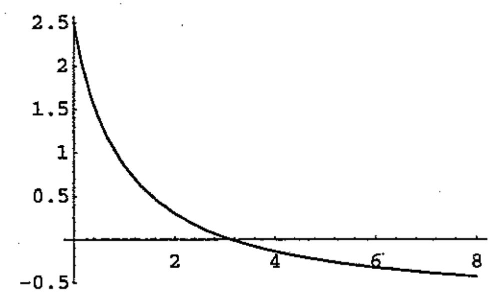

Figure 4

Appendix C

In this Appendix, we explain why in case (b2), before the (exogenous) growth-maximizing β, the relationship between mark-up and growth may be positive or negative depending on the absolute dimension of β .

Setting $\lambda = \alpha$ and $\phi = 0$, we have:

(A) $\gamma_N = \frac{\dot{N}}{N} = \left(\frac{\beta-1}{\eta\beta^2}\right)H - \rho\left(\frac{\beta^2-\beta+1}{\beta^2}\right);$

(B) $\gamma_Y = \left(\frac{\beta^2-2\beta+1}{\eta\beta^3}\right)H - \rho\left(\frac{\beta^3-2\beta^2+2\beta-1}{\beta^3}\right), \quad \beta \equiv \frac{1}{\alpha} > 1.$

From (A), it is clear that (for given η and ρ) γ_N depends both on β and H. In particular, the steady-state innovation growth rate will be strictly positive if and only if $H > \eta\rho\left(\frac{\beta^2-\beta+1}{\beta-1}\right)$. Moreover, combining (A) and (B), we can rewrite (B) as:

(B') $\gamma_Y = \left(\frac{\beta-1}{\beta}\right)\cdot\gamma_N$

Thus, when β is only slightly larger than one, then the constraint on H turns out to be binding and γ_N (and γ_Y) may easily be negative. Basically, in this first range of values of β, the lack of a strong market power enjoyed by the innovating firm requires a product market large enough to make the innovative activity profitable. On the other side, when β takes on values sufficiently larger than one (and less or equal to two), then the constraint on H is likely to be no more operative, so that now both γ_N and γ_Y may well be positive. In this case, the monopoly rents accruing to the successful innovator are so high that, in order to stimulate firms to innovate, there is no need for a large-sized potential market (large H).

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