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AN *INVERTED-U* RELATIONSHIP BETWEEN PRODUCT MARKET COMPETITION AND GROWTH IN AN EXTENDED ROMERIAN MODEL*

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Keywords: *Horizontal Differentiation, Product Market Competition, Technological Change, Endogenous Growth.*

JEL Classification: *D43, L16, O31, O41.*

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* I wish to thank, without implicating, R.Boucekkine, D. de la Croix and J. Ruiz for comments on an earlier draft of this paper. The usual disclaimer applies.

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1. INTRODUCTION

Over the last decades, economic performance (productivity levels and growth rates) in many EU countries has been sluggish, especially if compared with recent US achievement. In this respect, it is estimated that: *"…In the EU, there has been a steady decline of the average growth rate decade after decade and per-capita GDP has stagnated at about 70% of the US level since the early 1980s*" (Sapir *et al*., 2004). Many academics and policy makers now believe that one possible reason for this poor performance is to be found in the lack of competition in many EU product and factor input markets.[1]

How different market structures affect economic performance is a central issue in industrial economics. Text-book theory suggests that there are two fundamental channels through which product market competition (PMC) may influence efficiency. On the one hand, more intense PMC results in less slack in the use of inputs and better resource allocation. This should lead to higher productivity growth in the long run. On the other hand, since Schumpeter (1942) it is argued that more competition, by eroding the monopolistic rents that can be appropriated by the successful innovator, induces less incentives to R&D activity, so harming technological progress and economic growth in the future. The composition of these two effects (the positive *resource allocation effect* and the negative *profit incentive effect*) would seem to imply that the relationship between PMC and aggregate productivity growth might be *inverse U-shaped*. For low initial levels of competition, more PMC is beneficial to growth since it allows a substantial better use of resources, without hampering that much innovation incentives (the resource allocation effect outweighs the profit incentive effect and the correlation between competition and growth is positive). On the other hand, when PMC is sufficiently tough, more competition reduces drastically technological progress, improving only marginally the allocation of resources across economic activities (the profit incentive effect prevails over the resource allocation effect and the correlation between competition and growth is negative). Indeed, there exists some evidence of a *bell-shaped* relationship between product market competition and aggregate

[1] See, among others, Baily and Gersbach (1995) and Borsch-Supan (1998). A recent paper by Bayoumi *et al.* (2004) confirms this belief. Using a general-equilibrium simulation model featuring nominal rigidities and monopolistic competition in product and labour markets, they find that greater competition produces large effects on macroeconomic performance. In particular, they show that differences in competition can account for over half of the current gap in GDP per capita between the euro area countries and the US and that structural policies aimed to increase competition toward US levels increase output in the euro area by some 12.5%.

productivity growth (Aghion *et al*., 2002). Accordingly, attempts have been done to reformulate the basic Schumpeterian growth model with vertical differentiation (Aghion and Howitt, 1992) in order to account for this evidence (we discuss the related empirical and theoretical literature more fully later).

The aim of this paper is to demonstrate that it is possible to reconcile innovation-driven growth theory with the empirical evidence mentioned above through a simple extension of the basic Romer's model (1990) of horizontal innovation and deterministic R&D activity. Unlike Romer (1990), where more intense PMC unambiguously spurs economic growth, we assume that labour (and not physical capital, accumulated in the form of foregone consumption) is employed to produce intermediate inputs.[2] Apart from this hypothesis, the structure of our model economy remains the same as in the basic Romerian approach. In more detail, we postulate the existence of three sectors vertically integrated. A competitive final sector produces a homogeneous consumers good employing with constant returns to scale labour and all the existing varieties of intermediate goods as inputs. The intermediate goods sector consists of monopolistically competitive firms, each producing a differentiated variety. As already said, we assume that the production of one unit of intermediate good requires one unit of labour. Finally, the research activity produces designs (or blueprints) for new intermediate input varieties by employing labour together with the available stock of knowledge capital. Hence, in our model the labour input (available in fixed supply) is used in each economic activity. The introduction of this hypothesis within the simplest model of horizontal innovation (Romer, 1990) allows us to obtain an *inverse U-shaped* relationship between product market competition (that we proxy by the degree of substitutability across intermediate inputs) and growth. The intuition behind this result is as follows. For low levels of competition, tougher PMC reduces the price of capital goods and makes it profitable to substitute labour for durables in the production of the final output. The resources (labour) released by the downstream (or final output) sector can be employed for producing *both* more intermediates *and* ideas, which leads to higher growth. Hence, when competition is weak there exists a positive correlation between PMC and growth (the positive *resource allocation effect* outweighs the negative *profit incentive effect*). For high values of competition, stronger PMC continues to reduce the amount of labour devoted to the consumers good manufacture. At the

[2] In the remainder of the paper we will often use such expressions as *intermediate inputs*, *capital goods* or *durables*. All these terms are supposed to have the same meaning.

same time, however, the excessively large demand for labour coming now from the more competitive intermediate sector has the effect of attracting resources away from the growth-generating activity (R&D). In this case, more PMC in the intermediate sector generates a *trade-off* in the inter-sectoral allocation of labour between capital goods production and research activity and reduces unambiguously the investment in innovation. As a consequence, when competition is sufficiently strong the *resource allocation* and the *profit incentive effects* are both negative and reinforce each other in inducing a negative correlation between PMC and aggregate productivity growth.

The rest of the paper is organized as follows. In Section 2 we briefly review the literature (both empirical and theoretical) on the relationship between competition, innovation and growth and relate our contribution to the existing theoretical work. In Section 3 we set the model. In Section 4 we study the relationship between product market competition and growth as predicted by our model. In this section we also compare our results with those of the basic Romer's (1990) model and explain the differences between the two models by the interaction between the profit incentive and the resource allocation effects. Section 5 discusses in more detail one of these effects (the resource allocation). Finally, Section 6 summarises the main results and concludes.

2. THE RELATIONSHIP BETWEEN COMPETITION, INNOVATION AND GROWTH IN THE EXISTING LITERATURE

The discussion of the role of product market structure for innovation and, hence, economic growth dates back to Schumpeter (1942). However, it is only in the sixties that the *Schumpeterian hypothesis* (negative relationship between competition and innovation) starts to be empirically tested, thanks to the pioneering works of Scherer (1965; 1967).[3] These papers, and more recently those by Geroski (1994), Nickell (1996) and Blundell *et al* (1999), point to a positive correlation between competition, innovative output and growth, even though they do not uncover the possible reason(s) why competition may be growth-enhancing.

[3] For a comprehensive survey of empirical literature on the relationship between market structure and innovation see Cohen and Levin (1989), Scherer (1992), Cohen (1995), Symeonidis (1996) and Ahn (2002). For a review of the theoretical contributions to this research topic over the last twenty years, see, instead, Van Cayseele (1998).

Scott (1984) and Levin *et al*. (1985) were the first to find out an *inverted-U* relationship between R&D intensity and market concentration, with a peak at a 4-firm concentration ratio of around 50% to 65%, when not controlling for industry characteristics. A strong *bell-shaped* relationship between PMC and innovation has also (and more recently) been found by Aghion *et al*. (2002), analysing a range of industries drawn from a firm panel for the UK. The data concern UK listed firms over the period 1968-1996. Product market competition is measured by one minus the Lerner index (ratio of operating profits minus financial costs over sales), controlling for capital depreciation, advertising expenditures, and firm size. The long time series on firms in each industry allows the authors to control for industry level effects as well as common time effects. The *inverted-U* relationship between PMC and innovation is found to be robust to many alternative specifications and remains true in the data for many individual industries.

In sum, there exists (past and present) empirical evidence showing that the relationship between competition and growth is positive or, at most, *inverse U-shaped*. This finding is clearly at odds with the main result of the basic *Schumpeterian growth model* with vertical differentiation (Aghion and Howitt, 1992), according to which more competition in the product market unambiguously harms economic growth. In order to account for such evidence, the *Schumpeterian growth paradigm* has been recently re-formulated and extended in many directions.[4] A first strand of the literature (Aghion, Dewatripont and Rey, 1997; 1999) has emphasized the importance of agency issues: intensified product market competition can force managers to speed up the adoption of new technologies in order to avoid loss of control rights due to bankruptcy. This *disciplining effect* of product market competition is what causes higher economic growth rates in the future. An alternative approach, introduced by Aghion and Howitt (1996), has shown that more competition between new and old production lines (parameterised by increased substitutability between them) can make skilled workers more *adaptable* in switching to newer ones (*Lucas effect*). Holding the fixed supply of skilled workers constant, the consequence is an increase in the initial flow of workers into newly discovered products, which enhances the profitability of research (and, hence, economic growth) by reducing the cost of implementing a successful innovation. Still, all the works cited so far would predict a monotonic relationship between PMC and growth. This is not the case of Aghion, Harris and Vickers (1997)

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[4] See Aghion and Howitt (1998a, Chap. 7; 1998b; 2003); Aghion *et al*. (2002) and Bucci (2003) for surveys on this theoretical literature.

and Aghion *et al*. (2001), that extend the basic Schumpeterian model by allowing incumbent firms to innovate. In these papers, when PMC (as measured by either a greater elasticity of demand or as a switch from Cournot to Bertrand rivalry) is low, an increase will raise innovation through the *"escape competition effect"* on neck-and-neck firms, but when it becomes intense enough it may lower innovation through the traditional *"Schumpeterian effect"* on laggards. The contraposition of these two effects makes the relationship between competition and growth *inverse-U* shaped.

With respect to this literature, in the present paper we present a straightforward example of how such an *inverted-U* relationship between competition and growth may take place within the simplest *horizontal innovation-driven* growth model (Romer, 1990), provided that the scarce (or fixed supply) input is employed in each economic activity.

In two companion papers, Smulders and van de Klundert (1995) and van de Klundert and Smulders (1997) analyse the link between competition and growth within a framework where high-tech firms can rely on in-house skills in producing innovations and knowledge spillovers across firms in the R&D activity are explicitly taken into account. Unlike these contributions, here we keep the canonical hypothesis that there exists an aggregate R&D sector that produces *ideas* for the whole economy and assume that innovation increases the total stock of society's knowledge which, in turn, rises the ability to successfully innovate in the future. Moreover, we completely abstract from any form of strategic interaction among rivals (on both goods and factor markets).

3. AN EXTENDED ROMERIAN MODEL OF HORIZONTAL PRODUCT INNOVATION AND ENDOGENOUS GROWTH

Consider an economy where three sectors of activity are vertically integrated. In the research sector, firms use labour together with knowledge capital to engage in innovation activity. Innovation consists in discovering new designs (blueprints or patents) for firms operating in the capital goods sector. The number of designs existing at a certain point in time coincides with the number of intermediate input varieties and represents the actual stock of *non-rival* knowledge capital available in the economy. The intermediate good sector is composed of monopolistically competitive firms, each producing a differentiated variety *j*. To enter the intermediate sector, a firm must acquire a patent. By purchasing a patent a firm obtains not only the know-how to produce a specialised intermediate, but also a perpetual monopoly power over the sale of that particular intermediate good. Unlike Romer (1990), and following Grossman and Helpman (1991, Ch. 3), we assume that the production of one unit of intermediate goods requires one unit of labour, irrespective of their own variety.[5] In the competitive final output sector, firms produce a homogeneous good by employing labour and a set of intermediate inputs. Finally, we assume that the economy is populated by infinitely-lived agents who derive utility from consumption of final goods and supply labour inelastically. The population is constant and fully employed. Thus, one peculiarity of our model is that each sector of activity employs labour. This is the most important difference with respect to the Romer's (1990) seminal paper. We will show that introducing such hypothesis in that paper has crucial implications as far as the relationship between product market competition and aggregate economic growth is concerned.

Producers

In this sector atomistic producers engage in perfect competition. Following Spence (1976), Dixit and Stiglitz (1977), Ethier (1982) and Gancia and Zilibotti (2003), the technology to produce final goods (*Y*) is given by:

$$Y_t = (L_{Yt})^{1-\alpha} \int_0^{N_t} (x_{jt})^{\alpha}, \qquad 0 < \alpha < 1. \tag{1}$$

This production function exhibits constant returns to scale in the two *rival* inputs (labour, L_Y and durables, x_j). N_t is the measure of intermediate goods available at *t* and α is a parameter strictly between zero and one. A representative firm maximises its own instantaneous profits with respect to the *j-th* variety of intermediates, taking all prices as given. From the first order conditions, and with final output assumed to be the numeraire good, it is possible to derive the (inverse) demand of the downstream sector for the *j-th* intermediate input (from now on, and in order to ease the notation, time indexes will be omitted, unless this may induce confusion):

[5] In Romer (1990) it is assumed that the variable input in the intermediate goods production is physical capital and not labour. Hence, in that model the economy has two state variables (i.e. physical and knowledge capital).

$$p_j = \alpha\left(x_j\right)^{\alpha-1}\left(L_Y\right)^{1-\alpha} . \tag{2}$$

The equation above suggests that the demand for the *j-th* durable has price elasticity equal to $1/(1-\alpha)$. It is immediate to show that such elasticity (which is a function of α only) coincides with the substitution elasticity across two generic varieties of capital goods in the production of the final output. In a moment we will see that α also enters into the definition of the mark-up over the marginal cost set by local intermediate monopolists.

In the *intermediate sector*, capital good producers engage in *monopolistic competition*. Each firm produces one (and only one) horizontally differentiated intermediate good and must purchase a patented design before producing its own specialised durable. Thus, the price of the patent represents a fixed entry cost. We assume that each local intermediate monopolist has access to the same one-to-one technology, employing only labour (l_j):

$$x_j = l_j \quad , \qquad \forall j \in (0, N). \tag{3}$$

For given *N*, equation (3) implies that the total quantity of labour demanded by the intermediate sector at time *t* (L_j) is equal to:

$$\int_0^N (x_j) dj = \int_0^N (l_j) dj \equiv L_j . \tag{3a}$$

The firm producing the *j-th* variety, after bearing the expenses related to the purchase of the *j-th* idea, maximises at each point in time its own instantaneous profit function with respect to x_j and subject to the demand constraint (2). The resolution of this maximisation program gives the optimal price the *j-th* intermediate producer sets for one unit of its own output:

$$p_j = \frac{1}{\alpha} \cdot w_j = \frac{1}{\alpha} \cdot w = p , \qquad \forall j \in (0, N). \tag{4}$$

Thus, the mark-up charged over the marginal cost by each intermediate monopolist $(1/\alpha)$ is a negative function of the perceived price elasticity of the demand faced by the *j-th* capital good producer $(1/1-\alpha)$ and is constant. The marginal cost is represented by the wage rate accruing to labour employed in the intermediate sector (w_j). Due to the explicit assumption that labour is a homogeneous factor input and perfectly mobile across sectors, in equilibrium such wage rate will be the same (and equal to *w*) for all the economic activities where labour is employed.

Under the hypothesis of symmetry (i.e., x and, then, p are equal for each *j*), it is straightforward to derive the following results:

$$Nx = L_j \qquad \Rightarrow \qquad x = \frac{L_j}{N} \tag{3b}$$

$$\pi_j = (1-\alpha)px = \alpha(1-\alpha)(L_Y)^{1-\alpha}(L_j)^{\alpha} N^{-\alpha} = \pi, \qquad \forall j \in (0, N). \tag{4a}$$

In synthesis, in a symmetric equilibrium each firm producing intermediates will decide at time *t* to produce the same quantity of output (*x*), to sell it at the same price (*p*), accruing the same instantaneous profit rate (π) . This result follows from the symmetry of the production technology across intermediate firms (equation (3)).

R&D Sector

There are many competitive research firms undertaking R&D. These firms produce designs indexed by 0 through an upper bound $N \geq 0$. N thus measures the total stock of society's knowledge. Designs are patented and partially excludable, but non-rival and indispensable for capital goods production. With access to the available stock of knowledge N , research firms use labour to develop new blueprints. Following Romer (1990) and Grossman and Helpman (1991, p.58), the production of new designs is governed by:

$$\dot{N} = \frac{1}{\eta} N \cdot L_N, \qquad \eta > 0, \tag{5}$$

where $1/\eta$ is a parameter, L_N denotes the aggregate employment in research and N is the number of horizontally differentiated intermediate goods existing at time *t*.

An important assumption behind equation 5 is that innovation generates an intertemporal externality. In particular, inventing a new intermediate requires a labour input equal to η / N . The hypothesis that labour productivity increases with the stock of knowledge (*N*) can be justified by the idea that researchers benefit from accessing to the available total stock of applications for patents, obtaining inspiration to generate new designs (Gancia and Zilibotti, 2003, p. 5).[6]

Since the research sector is competitive, the price of the *j-th* design at time *t* will be equal to the discounted value of the flow of instantaneous profits that it is possible to make in the intermediate sector (to which the design is licensed) by the *j-th* intermediate firm from *t* onwards:

$$P_{Nt} = \int_t^{\infty} \pi_\tau \cdot e^{-r(\tau-t)} d\tau = \alpha(1-\alpha)\int_t^{\infty} \left(L_{Y\tau}\right)^{1-\alpha} \left(L_{j\tau}\right)^{\alpha} \left(N_\tau\right)^{-\alpha} \cdot e^{-r(\tau-t)} d\tau , \qquad \tau > t. \tag{6}$$

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. The fact that in equation (6) an infinite horizon is explicitly considered depends on the hypothesis that, once obtained a new blueprint from the R&D sector, the generic *j-th* producer of capital goods can accrue forever the monopoly profits deriving from the new variety being produced. This is a peculiar characteristic of horizontal differentiation growth models. Given P_{Nt}, the free-entry (or zero-profit) condition leads to:

$$P_N = \frac{\eta}{N} \cdot w_N = \frac{\eta}{N} \cdot w \qquad \Rightarrow \qquad w_N = w = \frac{N \cdot P_N}{\eta}, \tag{7}$$

where P_N assumes the value shown in equation (6) and w_N is the wage rate accruing to one unit of labour employed in the research sector (and equal to *w* in equilibrium). Equation (7) simply states that the entry of new firms into the sector will continue until the price that one obtains from the sale of an additional blueprint equals the production marginal cost of the blueprint itself.

Equations (6) and (7) can be used to highlight the two effects that a variation in α (and, hence, in the degree of product market competition, as we will explain in a while) may exert on the growth rate of this economy (equal to L_N / η). A change in the parameter α, for given *N* and

[6] The measurement of R&D spillovers has proved to be quite difficult and particularly controversial in the literature. See Griliches (1992) and Klette *et al.* (2000) for reviews of this evidence. Griliches (1992) concludes that R&D spillovers are not only present, but their magnitude may also be quite large, and social rates of return remain significantly above private rates. This conclusion is supported by Nadiri (1993), whose summary of the existing evidence points to the social rates of return to R&D varying from 20% to over 100%.

for given sectoral distribution of the labour input (L_Y and L_j), determines a variation in P_N and, thus, in the incentives for firms to perform R&D activity (the engine of growth in the model). This is the traditional *profit incentive effect* one may find in most of the R&D-based growth models. In addition to this one, in this paper we want to draw attention on a *resource allocation effect*, as well. For given *N*, the original change in α determines also, through P_N , a variation of *w* for equation (7) to hold in equilibrium. The joint variation of α , P_N and *w* will induce some substitution between intermediate goods and labour in the final output sector and will give rise to a re-allocation of the entire fixed-supply labour input among all the sectors of the economy (thus influencing both L_N and the equilibrium growth rate). We will devote the entire Section 5 of this paper to a more detailed discussion of these two effects (the *profit incentive* and the *resource allocation effect*). The description of the preferences closes the model.

Consumers

Total output produced in this economy (Y) can be only consumed. Population is stationary and there exists full employment. For the sake of simplicity, we normalize population to one and postulate the existence of an infinitely-lived representative consumer with perfect foresight. This consumer is endowed with a fixed amount of labour (*L*) that he/she allocates to the production of the homogeneous final good (L_Y), intermediates (L_j) and research (L_N). This consumer also owns all the firms operating in this economy and maximises, under constraint, the discounted value of his/her lifetime utility:

$$\begin{cases} \underset{\{Y\}_{t=0}^{\infty}}{Max} U_0 = \int_0^{\infty} e^{-\rho t} \cdot \log(Y_t) dt \\ s.t.: \\ \dot{W}_t = w_t \cdot L + r_t \cdot W_t - Y_t \end{cases} \tag{8}$$

The first order conditions of this problem must satisfy the constraint on $\dot{W}_t$, together with the transversality condition:

$$\lim_{t\to\infty} \mu_t \cdot W_t = 0 .$$

Symbols have the following meaning: U_0 is the intertemporal utility function; $\log(Y)$ is the instantaneous utility function of the representative agent;[7] Y denotes his/her consumption of the homogeneous final good; $\rho(>0)$ is the individual discount factor; μ is the co-state variable and W, $w \cdot L$, $r \cdot W$ and r are respectively the total wealth of the agent (measured in units of final good), his/her labour income, his/her interest income and the (exogenous) interest rate.

The solution to the problem above yields a standard Euler equation:

$$\gamma_Y = \frac{\dot{Y}_t}{Y_t} = r_t - \rho. \tag{9}$$

In the model there is no physical capital and savings are used to finance innovative investments. In the steady state equilibrium, when the growth rate of output (γ_Y) is constant and positive, r turns out to be constant and positive, as well (see next sub-section).

The equilibrium in the labour market and the steady-state

In order to determine the optimal allocation of the given supply of labour (L) to the three sectors using this resource (and producing respectively the consumers good, intermediates and research), we equalise the wage rates accrued by one unit of labour in each of the just mentioned activities. Notice that in this economy labour is supposed to be a homogeneous input and perfectly mobile across sectors. Thus, it must be compensated according to a unique wage rate. As a result, the following three conditions must simultaneously be checked:

$$L_{jt} + L_{Nt} + L_{Yt} = L, \qquad \forall t; \tag{10}$$
$$w_j = w_Y; \tag{11}$$
$$w_j = w_N. \tag{12}$$

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[7] Following Grossman and Helpman (1991) we assume that the instantaneous utility function of the representative agent is logarithmic. Using more general isoelastic functions does not alter the results.

Equation (10) is a resource constraint, saying that at any point in time the sum of the labour demands coming from each activity must be equal to the total available fixed supply (L). Equations (11) and (12) together state that the wage earned by one unit of labour is to be the same irrespective of the sector where that unit of labour is actually employed.

The simultaneous resolution of the equations system (10) through (12) yields the following steady-state equilibrium values for the relevant variables of the model (see notes to the referees not to be published for mathematical details):

$$r = \frac{\alpha(1-\alpha)^2 L + \alpha\eta\rho\left(\alpha^2 - 2\alpha + 2\right)}{\eta}; \tag{13}$$

$$L_N = \alpha(1-\alpha)L - \eta\rho\left(\alpha^2 - \alpha + 1\right); \tag{14}$$

$$L_j = \alpha^2(L + \eta\rho); \tag{15}$$

$$L_Y = (1-\alpha)(L + \eta\rho); \tag{16}$$

$$\gamma_Y \equiv \frac{\dot{Y}}{Y} = r - \rho = \frac{\alpha(1-\alpha)^2 L + \eta\rho\left[\alpha\left(\alpha^2 - 2\alpha + 2\right) - 1\right]}{\eta}; \tag{17}$$

$$\gamma_N \equiv \frac{\dot{N}}{N} = \frac{1}{\eta} L_N = \frac{\alpha(1-\alpha)L - \eta\rho\left(\alpha^2 - \alpha + 1\right)}{\eta}; \tag{18}$$

Hence, the growth rate of this economy (γ_Y) is a function of the technological and preference parameters of the model (η and ρ), and α (the inverse of the mark-up rate charged by intermediate-sector firms). It also positively depends on the available labour supply, L (scale effect).[8]

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[8] The presence of scale effects in the model is due to our specification of the R&D technology (which is the same used by Romer, 1990). As Jones (1995a,b) points out, data do not corroborate the scale effects-hypothesis and, then, it should be rejected on empirical grounds. Many theoretical works are now available and that successfully remove the scale effect prediction from an innovation-driven growth model (see, among others, Aghion and Howitt, 1998a, chap.12; Dinopoulos and Thompson, 1999; Jones, 1999; Jones, 2003, pp. 36-55; Bucci, 2003, pp. 280-83 for surveys). Indeed, it is out of the scope of the present article to build an endogenous growth model without scale effects, our aim here being, instead, to show that one easy way to reconcile innovation-driven growth theory with the empirical evidence on the relationship between competition and growth consists in using the simplest extension of the basic Romer's (1990) approach with horizontal and deterministic R&D.

4. SECTORAL DISTRIBUTION OF LABOUR AND THE RELATIONSHIP BETWEEN PRODUCT MARKET COMPETITION AND GROWTH

Product market competition may play an important role in economic growth in two fundamental respects. First of all, it allows to allocate the available resources to the best uses, while improving the performance of labour markets (Blanchard, 2004). At the same time, and according to *Schumpeterian* growth theory, because it erodes monopoly rents, product market competition is detrimental to innovation and economic growth. The negative effect that a tougher product market competition has on innovation (and, thus, on growth) is evident from equation (6). The presence of lower profits due to more intense competition in the intermediate sector makes innovation less rewarding (*ceteris paribus*, the price of a new design P_N decreases with π), and this in turn contributes to reduce firms' investment in R&D and economic growth. Due to the specific assumptions made (namely Dixit-Stiglitz (1977) technology in the downstream sector and no strategic interaction between intermediate sectors), in the model of the previous sections these two effects of product market competition on economic growth (respectively the *resource allocation* and the *profit incentive effects*) are closely related to each other, since more competition in the product market changes the distribution of the scarce resource (labour) across economic activities and, then, influences both firms' profits and incentives to innovate.

In this section, we analyse the long-run relationship between competition and growth in the extended Romerian model of the previous paragraphs and explain such a relationship by the interplay between the two effects mentioned above. In what follows we use the parameter α as a proxy for the degree of product market competition in the capital goods sector. Indeed, any definition of the intensity of competition involves the idea that more intense competition should lead to lower mark-ups and, thus, to lower prices (see Sutton, 1991 and Denicolò and Zanchettin, 2003). In our case, the mark-up set over the marginal cost by each capital-goods producer in the symmetric equilibrium is equal to $1/\alpha$. As a consequence, the higher α, the higher the elasticity of substitution between two generic varieties of intermediate inputs (equal to $1/1-\alpha$), and the lower the mark-up rate. In a word, the *"toughness"* of competition in the intermediate sector positively depends on the level of α. The limiting case of $\alpha = 0$ defines the minimal degree of competition, whereas the opposite limiting case of $\alpha = 1$ is the case of perfect competition. Besides being a monotonically increasing transformation of the elasticity of substitution between two generic varieties of durables in the final output production, α is also a monotonically increasing transformation of the price demand elasticity faced by each intermediate firm (and equal, again, to $1/1-\alpha$). Therefore, it corresponds to standard measures of competition in this model. Ideally, one would like to disentangle the effects of a change in the degree of competition from those associated with changes in the structural (taste and/or technology) parameters that ultimately determine the elasticity of demand (see Benassy, 1998). However, in order to make the mechanics of the interaction between the above-mentioned *resource allocation* and *profit incentive effects* as much clear as possible within our model, we compare our results with those obtained in the original Romer's (1990) paper of horizontal innovation and endogenous technological change as presented in Aghion and Howitt (1998a, pp.35-39) and Gancia and Zilibotti (2003, pp.4-8) - A-H-G-Z-R model from now on. As is well known, in all the first-generation innovation-driven growth models (including Romer, 1990) the only possible measure of product market competition is the one related to the elasticity of demand/elasticity of substitution across intermediates.[9]

The most remarkable difference between A-H-G-Z-R and our model is that in the former output can be either consumed or saved as new physical capital. Forgone consumption is then used to produce durables. It is assumed that one unit of capital can produce one unit of an intermediate good, the marginal cost of production being, then, the interest rate (*r*) instead of the wage rate accruing to one unit of labour as in our model. The assumption that physical capital can be accumulated as forgone output amounts to assuming that capital goods are produced in a separate sector that has the same technology as the final output sector. This means that in the A-H-G-Z-R model local intermediate producers use labour only indirectly (through forgone consumption), rather than directly, as we explicitly assume in equation 3. Otherwise, the final output and the research sectors use the same technologies reported respectively in equations 1 and 5. Since in A-H-G-Z-R labour can be used either in manufacturing the final good (L_Y) or, alternatively, in research activity (L_N), the labour market clearing condition and the hypothesis of labour mobility across sectors imply respectively:

$$L = L_Y + L_N, \qquad \forall t \tag{a}$$

$$w_Y = w_N. \tag{b}$$

[9] See Aghion and Howitt (1997).

Solving the two-equations system above leads to the following steady state values of r, L_N, L_Y, γ_Y and γ_N (see Aghion and Howitt, 1998a, pp.35-99; Bucci, 2003, pp. 257-258; Gancia and Zilibotti, 2003, pp.4-8, and recall that in our case the elasticity of intertemporal substitution equals one, as we use a logarithmic rather than isoelastic instantaneous utility function):

$$r = \left(\frac{1}{\eta}L + \rho\right)\left(\frac{\alpha}{1+\alpha}\right) \tag{19}$$

$$L_N = \left(\frac{1}{1+\alpha}\right)(\alpha L - \eta\rho) \tag{20}$$

$$L_Y = \left(\frac{1}{1+\alpha}\right)(L + \eta\rho) \tag{21}$$

$$\gamma_Y = \frac{\dot{Y}}{Y} = \frac{\frac{\alpha}{\eta}L - \rho}{1+\alpha}, \tag{22}$$

$$\gamma_N = \frac{\dot{N}}{N} = \frac{\alpha L - \eta\rho}{\eta(1+\alpha)}. \tag{23}$$

From equation (22) the relationship between product market competition (α) and the aggregate growth rate (γ_Y) takes the following shape in the A-H-G-Z-R model:[10]

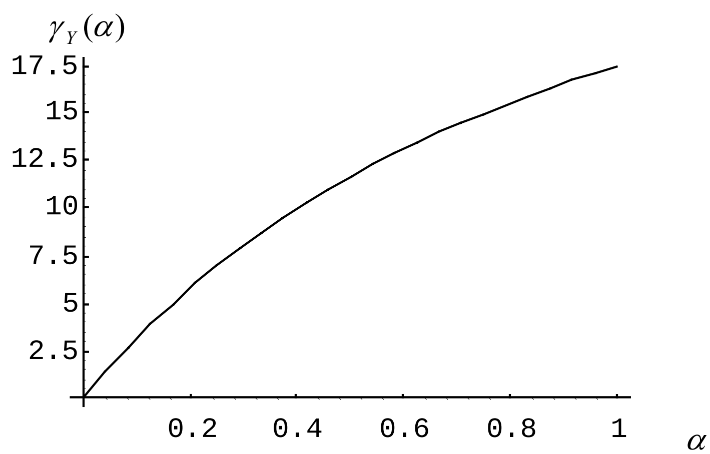

Figure 1

The Competition-Growth Relationship in the basic Aghion-Howitt-Gancia-Zilibotti-Romer (A-H-G-Z-R) Model

[10] In drawing Figure 1, and in order to obtain a positive solution for the aggregate growth rate of the economy, we used the following parameters values: *L=35*, $\eta = 1$, $\rho = 0.03$. For the same reason, we studied the behaviour of $\gamma_Y(\alpha)$ over the range: $\alpha \in [0.000858 ; 1]$.

According to Figure 1, in the A-H-G-Z-R model the aggregate growth rate monotonically increases with α. The intuition behind this result is as follows: an increase in the degree of competition in the intermediate sector (an increase of α) reduces the price of durables and makes it profitable to substitute capital goods for labour in the production of the homogeneous final good. Consequently, the demand for labour in the final output sector (L_Y) decreases with α. When α is sufficiently large, all the available labour input (*L*) ends up to be allocated to research (the only other activity, besides the consumers good production, where labour can be employed), which leads to ever and ever increasing aggregate economic growth rates. From Figure 1 above, it is clear that in this case the *resource allocation effect* (the positive effect that an increase of α has on L_N in equation 20) prevails over the *profit incentive effect* (the negative effect that, for given sectoral distribution of the labour input, an increase of product market competition has on intermediate firms' profits and, thus, on their incentive to innovate in equation 6) for each level of α.

Contrary to A-H-G-Z-R, it is possible to show that in our model (where labour is employed in each economic sector) there exists an optimal α (that we denote by α^*), which maximises the aggregate growth rate. This is due to the fact that now, and unlike the previous case, the *resource allocation* effect is positive and dominates the negative *profit incentive effect* only up to a threshold value of α (α^*). For values of α higher than α^*, instead, the *resource allocation effect* becomes negative itself and reinforces the *profit incentive effect*, which leads to a negative relationship between competition and growth. Therefore, in the extended Romerian model we have presented in this paper (equations 13 through 18) this relationship is *inverse U-shaped*:[11]

[11] In drawing Figure 2 we used the same parameters values as in Figure 1 (*L=35*, $\eta = 1$, $\rho = 0.03$) and studied the behaviour of $\gamma_Y(\alpha)$ over the range: $\alpha \in [0.000858;\ 0.999142]$. Again, in so doing we were able to obtain a positive growth rate for each value of α. With these parameters values, the maximum level of economic growth ($\gamma_Y \cong 5{,}17$) is attained when $\alpha \cong 0{,}334$.

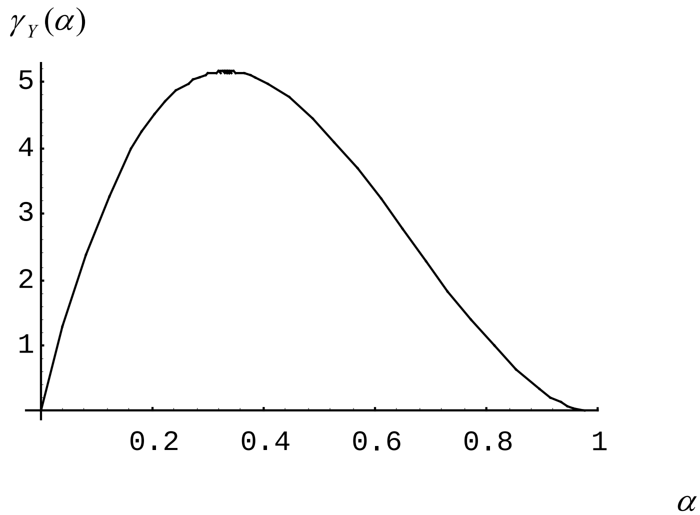

Figure 2

The Competition-Growth Relationship in the extended Romerian model of this paper

We can state now the following:

Proposition

In an extended Romerian model with horizontal innovation and deterministic R&D activity, as the one described by the equilibrium equations (13) through (18), there exists an inverted-U relationship between product market competition (α) and aggregate economic growth (γ_Y), provided that the intermediate sector employs directly the fixed-supply input (labour).

This result is due to the interaction between the *resource allocation* and the *profit incentive effects*. Suppose, indeed, that labour is directly employed in each economic activity. At low initial levels of α, an increase of competition reduces the amount of labour devoted to final output manufacturing (L_Y) and the resources released by this sector can be allocated both to the production of durables (L_j) and research (L_N). Thus, L_j and L_N all unambiguously increase with α.[12] In Figure 2 it is clear that for values of α lower than α^*, the relationship between product market competition and growth is positive, meaning that in this interval (as in the basic

[12] See equations 14, 15 and 16 in the main text.

A-H-G-Z-R model) the positive *resource allocation effect* (bigger L_N) outweighs the negative *profit incentive effect*.

Instead, at higher levels of α, an increase of product market competition reduces the amount of labour devoted to final output manufacturing (L_Y) *and* research (L_N) and continues to increase L_j. In other words, with α large, further increases of competition imply more capital goods production and more labour demand coming from the intermediate sector.[13] However, unlike what happens in the previous case, now the additional resources requested for the production of durables are drawn not only from the downstream sector, but also from research (L_N is lower). In Figure 2 it is clear that for values of α greater than α^*, product market competition and growth are negatively correlated, meaning that in this interval not only the *profit incentive*, but also the *resource allocation effect* is negative.

In brief, the above proposition says that, when (a version of) the basic Romer's (1990) model is extended by assuming that the scarce input is employed in each economic sector, a non-monotonic relationship between product market competition and growth may take place.

5. THE PROFIT INCENTIVE AND RESOURCE ALLOCATION EFFECTS: A DISCUSSION

In the previous sections we have often referred to the *resource competition effect* (that is competition between growth-enhancing activities -R&D- and non growth-enhancing ones - manufacturing- for the same factor input). We have shown that such an effect is potentially able to modify the steady state relationship between product market competition and growth. Consequently, it seems to be a very interesting feature of variety expanding growth models and, strangely enough, it has not been addressed before. For this reason, in this section we briefly discuss the mechanics of this effect and its relationship with the more conventional *profit incentive effect*, on which most papers that have investigated the link between competition and growth have focussed.

[13] Recall that durables are produced one-to-one with labour.

According to the *profit-incentive-effect*, a lower elasticity of substitution (a lower α) reduces the price demand elasticity faced by intermediate producers (equal to $1/1-\alpha$) and raises both their monopoly power and profits. This means that innovation pays more, which tends to increase growth. Therefore, the profit incentive effect seems to predict an unambiguously negative relationship between product market competition and economic growth (Schumpeter, 1942). But we have shown before that this is certainly not true in the basic variety expanding model by A-H-G-Z-R and that, for this reason, a *resource allocation effect* should also be considered. According to this effect, a lower elasticity of substitution (a lower α) makes a given number of varieties less similar to each other and therefore more productive. In turn, this raises the productivity of all factors that are used in combination with intermediates. Hence, if labour (the scarce resource) is an important input in final output, then the productivity of labour in this sector rises and the demand for L_Y increases as well. This demand competes with the demand for *L* coming from the other sectors of the economy (especially from research) and has the effect of attracting labour away from the growth-generating activities. This is exactly what happens in the A-H-G-Z-R model, where labour may only be used for producing final goods and ideas. In this model, because the relationship between product market competition and growth is positive, the *resource allocation effect* is unambiguously positive and prevails over the *profit incentive effect* for each value of α.

On the other hand, when the inter-sectoral competition for labour is particularly strong (as in our model, where this factor input is employed everywhere), an increase in the degree of product market competition continues to display a definitely negative *profit incentive effect*, but in this case the *resource allocation effect* is no longer positive for each value of α. Indeed, for α lower than a threshold level, both the intermediate and research sectors may benefit (in terms of resources devoted to such activities) from a reduction of the labour demand coming from the final output sector and due to an increase of competition. So, in this case the *resource competition effect* is still positive (L_N increases). When α is sufficiently large, instead, an increase of competition implies that more resources are devoted to capital goods and less resources are employed in the final output sector and research activity. In other words, when PMC is already tough, further competition in the intermediate sector generates a *trade-off* in the sectoral distribution of labour between capital goods production and R&D and the *resource* *competition effect* becomes negative (L_N decreases). Together with the fact that the *profit incentive effect* is always negative (for each value of α), this implies that the relationship between product market competition and growth is unambiguously negative when α is greater than a given lower limit.

The existence of this trade-off in the inter-sectoral allocation of labour between the intermediate and the research sectors when the degree of competition is higher than a threshold value and increases further implies that there will exist a growth-maximising α.

6. CONCLUDING REMARKS

This paper has re-considered the relationship between product market competition and growth. We have shown that an *inverted-U relationship* between these two variables may take place within a simple extension of the basic Romer's (1990) model, provided that labour (instead of forgone consumption) is employed in the production of durables. We modelled product market competition by the elasticity of substitution across varieties of capital goods. Competition and growth are linked by two channels. More competition in the product market harms growth because it erodes the monopoly rents that can potentially be appropriated by the successful innovator, and thus reduces his/her incentive to innovate (this is the traditional *profit incentive* or *Schumpeterian effect*). At the same time, an increase of product market competition changes the distribution of labour across sectors and, then, impacts the amount of resources devoted to R&D (the *resource allocation effect*). Contrary to the *profit incentive effect* (which is always negative along the entire range of competition intensity), we found that the *resource allocation effect* may be either positive or negative. At low initial levels of product market competition, a further increase of competition reduces the price of intermediate inputs and makes it profitable to substitute capital goods for labour in the final output sector. This implies that more resources can be allocated to the production of intermediates and especially to innovation activity (the *resource allocation effect* is positive). However, when the level of product market competition is high enough, the demand for labour coming from the intermediate sector becomes excessively large with respect to the available fixed supply. This implies that resources are drawn not only from the final output sector (as before), but also from research activity (the *resource allocation effect* becomes negative). Hence, the growing level of product market competition in the intermediate sector generates a *trade-off* in the inter-sectoral allocation of labour between capital goods production and innovation activity. It is exactly the existence of this trade-off that allows us to obtain a non-monotonic relationship between competition and growth. Starting from a low level of competition, the positive *resource allocation effect* outweighs the negative *profit incentive effect*, so that competition and growth are positively correlated. When the level of product market competition is sufficiently high, the *resource allocation* and the *profit incentive effects* are both negative and the relationship between competition and growth becomes unambiguously negative, too.

Our findings strongly depend on the hypothesis (common to all the early innovation-based growth models, including Romer's) that there exists no strategic interaction among rivals on goods and factor markets. It could be interesting to analyse how, within our (perhaps over-simplified) Romerian framework, the competition-growth relationship may change when one explicitly allows for the presence of some kind of interaction between firms.

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