

Università degli Studi di Milano

Economics

Year 2006

Paper 1

Horizontal Innovation-Based Growth and
Product Market Competition

alberto bucci
University of Milan

Carmelo P. Parello
Catholic University of Louvain

This working paper site is hosted by The Berkeley Electronic Press (bepress) and may not be commercially reproduced without the publisher's permission.

<http://services.bepress.com/unimi/economics/1>

Copyright ©2006 by the authors.

Horizontal Innovation-Based Growth and Product Market Competition

Abstract

The influence of the degree of competition in the goods market on growth is analyzed by developing an endogenous growth model with horizontal innovation. Product market competition is measured by (1- Lerner index) and depends on both the share of factor inputs in total income and on the elasticity of substitution across goods. We find that the shape of the relationship between competition and growth can change dramatically according to which proxy of competition is used. We interpret our results in terms of the interplay between the resource allocation and the profit incentive effects.

HORIZONTAL INNOVATION-BASED GROWTH AND PRODUCT MARKET COMPETITION†

Alberto BUCCI*

Carmelo Pierpaolo PARELLO**

Abstract

The influence of the degree of competition in the goods market on growth is analyzed by developing an endogenous growth model with horizontal innovation. Product market competition is measured by (1- Lerner index) and depends on both the share of factor inputs in total income and on the elasticity of substitution across goods. We find that the shape of the relationship between competition and growth can change dramatically according to which proxy of competition is used. We interpret our results in terms of the interplay between the resource allocation and the profit incentive effects.

Keywords: *Innovation, Product Market Competition, Endogenous Growth, Scale Effects.*

JEL Classification: *L16, O31, O41*

† We thank R. Boucekkine for insightful comments on a first draft of this paper. Alberto Bucci gratefully acknowledges financial support from MIUR (*Italian Ministry for University and Scientific Research, grant number 2005131555_003*). Carmelo Pierpaolo Parello gratefully acknowledges financial support from the Belgian Research Programmes “*Poles d’Attraction Inter-universitaires*”, PAI P5/21, and “*Action de Recherches Concertée*”, 03/08-302. The usual disclaimers apply.

* **Corresponding Author:** University of Milan, Department of Economics, Business and Statistics (DEAS), via Conservatorio, 7 I-20122 Milan, Italy. Tel.: ++39 2 50321.463; E-mail: alberto.bucci@unimi.it

**Catholic University of Louvain, Department of Economics and IRES, Place Montesquieu, 3 B-1348 Louvain-la-Neuve, Belgium. Tel.: ++32 10 474484 ; E-mail : parello@ires.ucl.ac.be

1. INTRODUCTION

The interest in the study of the relationship between product market competition (PMC, henceforth), innovation and growth has always been at the core of economists' research agenda. Schumpeter (1942) was among the first to recognize the need to provide the successful innovator with some form of monopoly power in order to stimulate investment in research and development (R&D) activity and, thus economic growth. The idea that innovation and growth should increase with market power can be found not only in the IO literature (for example, Dasgupta and Stiglitz, 1980; Caballero and Jaffe, 1993), but also in the first generation of Schumpeterian growth models (namely, Aghion and Howitt, 1992). However, empirical work has never completely corroborated such a theoretical prediction.

Indeed, although it is only in the sixties that the *Schumpeterian hypothesis* (negative relationship between competition and innovation) starts being empirically tested, thanks to the pioneering works of Scherer (1965; 1967),¹ 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.

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 similar result (*bell-shaped* relationship between PMC and innovation) is also present in Aghion *et al.* (2005), analyzing a range of industries drawn from a firm panel for the UK. The data concern UK listed firms over the period 1968-1996. In this paper, PMC 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.

¹ 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 Van Cayseele (1998).

In sum, there exists (past and present) micro-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 basic *Schumpeterian growth paradigm*. For this reason, such a paradigm has been recently re-formulated and extended along many directions.² A first strand of the literature (Aghion, Dewatripont and Rey, 1997; 1999) has emphasized the importance of agency issues: intensified PMC can force managers to speed up the adoption of new technologies in order to avoid loss of control rights due to bankruptcy. This effect of PMC causes, then, higher economic growth rates in the future.³ An alternative approach, introduced by Aghion and Howitt (1996), has shown that more competition between new and old production lines (parameterized by increased substitutability between them) can make skilled workers more adaptable in switching to newer ones. Holding the fixed supply of skilled workers constant, this in turn leads to 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, the two works cited so far would predict a monotonic relationship between PMC and growth. This is not the case of Aghion, Harris and Vickers (1997) and Aghion *et al.* (2001) that extend the basic Schumpeterian model with creative destruction 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.⁴

With respect to the literature mentioned thus far, the aim of the present paper is to analyze to which extent an *inverted-U* relationship between competition and growth may take place in the case in which innovation-based growth is a process generating new varieties of horizontally-differentiated products, rather than quality-improved new products. In this respect, we keep the

² See Aghion and Griffith (2005), Aghion and Howitt (1998a, Chap. 7; 1998b; 2005); Aghion *et al.* (2005) and Bucci (2003) for surveys on this theoretical literature.

³ Indeed, the authors show that the relationship between PMC and innovation is always negative if most firms are profit-maximizing, whereas it is always positive if most firms are governed by “*satisficing*” managers who mainly care about the firm remaining in activity.

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. Moreover, we completely abstract from any form of strategic interaction among rivals (on both goods and factors markets).

While continuing to measure PMC by one minus the Lerner index, the originality of our contribution consists in the fact that this measure of competition is the result of the interaction between two additional variables determining, respectively, the elasticity of substitution across (intermediate) goods and the share of factor inputs in total income. Using a technology for the final goods sector similar to Jones and Williams (2000), we show that results concerning the shape of the relationship between PMC and growth may change dramatically.

Romer (1990) was the first to study extensively the consequences for aggregate economic growth of horizontal product innovation, but the analysis of the relationship between competition and growth was not at the core of his paper. Two further differences characterize our work with respect to Romer's (1990). The first is that we restrict our attention to the case of an economy where a fixed supply input (labor, in our case) can be employed simultaneously in each economic activity. The other difference is that our model does not display any scale effect (the prediction according to which larger economies should exhibit a higher real per-capita income growth rate).

The remainder of the article is structured as follows. In section 2 we set the model. In section 3 we examine its balanced-growth path (BGP) equilibrium properties. Sections 4 and 5 contain the main results of the paper. In Section 4 we introduce and discuss our measure of competition in the goods market and analyze the link between PMC and economic growth. We show that, if competition is proxied by the share of intermediate inputs in total income, then the relationship between PMC and growth may well be inverse-U shaped. On the other hand, this relationship becomes U-shaped when we proxy competition by the parameter that determines the elasticity of substitution across intermediate goods. We explain such a difference in our results through the interplay between two effects (the *resource allocation* and the *profit incentive effects*). Finally, section 5 concludes.

⁴ In an alternative setting, Smulders and van de Klundert (1995) and van de Klundert and Smulders (1997) analyze the link between competition and growth under the assumption that high-tech firms can rely on *in-house* skills in producing innovations and that knowledge spillovers across firms in the R&D activity may occur.

2. THE MODEL

Consider an economy where three sectors of activity are vertically integrated. In the research sector, firms use labor together with knowledge capital to engage in innovation activity. Innovation consists in discovering new blueprints for firms operating in the capital goods sector. The number of blueprints 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 goods 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 a perpetual monopoly power over the sale of a specialized intermediate. Unlike Romer (1990), and following Grossman and Helpman (1991, Ch. 3), we assume that the production of one unit of intermediates requires one unit of labor, irrespective of its own variety.⁵ In the final output sector, firms produce a homogeneous consumption good by employing labor and the available set of intermediate inputs.

2.1 Producers

In the *final output sector* atomistic producers engage in perfect competition. Following Spence (1976), Dixit and Stiglitz (1977), Ethier (1982) and Jones and Williams (2000), we postulate that the technology to produce the homogeneous consumption good (Y) is given by:

$$Y_t = (L_{Yt})^{1-\alpha} \left[\int_0^{N_t} (x_{jt})^{\eta\alpha} dj \right]^{1/\eta}, \quad 0 < \alpha < 1, \quad 0 < \frac{1}{1+\alpha} < \eta < \frac{1}{\alpha}. \quad (1)$$

According to this technology, at any time period t final output (Y_t , the numeraire good) is obtained by combining with constant returns to scale labor (L_{Yt}) and N different varieties of intermediate inputs, each of which is employed in the quantity x_j . In a symmetric equilibrium where the total production of intermediates is evenly spread across the N brands, α measures the share of total output going to capital goods (*ShK*). Instead, $(1 - \alpha)$ is the share of output accruing

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

to labor (ShL). Finally, η is a parameter that determines the elasticity of substitution between intermediate inputs, equal to:

$$e = \frac{1}{1 - \eta(1 - ShL)}, \quad ShL \equiv 1 - \alpha.$$

In Romer (1990), η equals one implying that the elasticity of substitution depends on the inverse of the labor share in income (ShL). In the more general case of $\eta \neq 1$, the restriction $0 < 1/(1 + \alpha) < \eta < 1/\alpha$ ensures simultaneously that intermediate inputs are imperfectly substitutable in production ($e > 1$) and that (as we are going to show in a moment) the demand curve for intermediate good j slopes downward, the markup on intermediate goods is greater than unity and the instantaneous profit accruing at t to the j -th capital good producer in a symmetric equilibrium is inversely related to the number of varieties existing at that date.

As the industry is competitive, in equilibrium each input receives its own marginal product (in terms of the numeraire good):

$$p_{jt} = \alpha(L_{Yt})^{1-\alpha} \left[\int_0^{N_t} (x_{jt})^{\eta\alpha} dj \right]^{\frac{1}{\eta}-1} (x_{jt})^{\eta\alpha-1}; \quad (2)$$

$$w_{Yt} = (1 - \alpha) \frac{Y_t}{L_{Yt}}. \quad (3)$$

In equations (2) and (3), p_{jt} and w_{Yt} represent, respectively, the inverse demand function faced at time t by the generic j -th intermediate producer and the labor demand coming from final output firms.

In the *intermediate sector* producers of capital goods engage in *monopolistic competition*. Each firm produces one (and only one) horizontally differentiated intermediate and must purchase a patented design before producing its own specialized 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 labor (l_j) only:

$$x_{jt} = l_{jt}, \quad \forall j \in [0, N_t], \quad \text{with } N_t \in [0, \infty). \quad (4)$$

For given N , equation (4) implies that the total amount of labor demanded by the intermediate sector at time t (L_{jt}) is:

$$\int_0^{N_t} x_{jt} dj = \int_0^{N_t} l_{jt} dj \equiv L_{jt} . \quad (4')$$

The firm producing the j -th variety, after bearing the expenses related to the purchase of the j -th idea, maximizes at each point in time its own instantaneous profit with respect to x_{jt} and subject to the demand constraint (2). Under the assumption that in the intermediate sector the number of firms is so large that each of them is unconstrained by competitors offering an equivalent product,⁶ the resolution of this maximization program gives the optimal price set by the generic j -th intermediate producer for one unit of its own output:

$$p_{jt} = p_t = mw_{jt} = mw_t, \quad \forall j \in [0, N_t], \quad m \equiv \frac{1}{\eta(1 - ShL)} = \frac{1}{\eta\alpha} . \quad (5)$$

Thus, the markup over the marginal cost (m) is a negative function of the elasticity of substitution between intermediate inputs (η) and is constant. The marginal cost is represented by the wage rate accruing to labor employed in the intermediate sector (w_j). Due to the hypothesis that labor is a homogeneous factor input and perfectly mobile across sectors, in equilibrium such wage rate will be the same (w) for each economic activity where labor is employed.

When $\nu = 1$ (Romer, 1990) the monopoly markup chosen by intermediate firms depends only on the factor input shares in income ($\alpha \equiv ShK = 1 - ShL$). Instead, when $\nu \neq 1$, using the aggregate technology of equation (1) has the advantage of severing the overly restrictive link between the markup and the factor input shares (see Jones and Williams, 2000, p. 68), since in this case the markup depends also on the parameter of substitution ν .

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

$$N_t x_t = L_{jt} = x_t = \frac{L_{jt}}{N_t}; \quad (4'')$$

⁶ This amounts to assuming that each intermediate goods firm acts as local monopolist. Formally,

$$\frac{\partial}{\partial x_{jt}} \left[\int_0^{N_t} (x_{jt})^{\eta\alpha} dj \right] = 0 .$$

$$\pi_{jt} = \left(1 - \frac{1}{m}\right) \alpha (L_{Yt})^{1-\alpha} (L_{jt})^\alpha (N_t)^{\frac{1-\eta(1+\alpha)}{\eta}} = \left(1 - \frac{1}{m}\right) \alpha \frac{Y_t}{N_t} = \pi_t \quad \forall j \in [0, N_t]. \quad (6)$$

In words, in a symmetric equilibrium each firm producing intermediates will decide at time t to produce the same quantity of output (x_t), to sell it at the same price (p_t), accruing the same instantaneous profit rate (π_t). This result follows from the symmetry of the production technology across intermediate firms (equation 4). As we are dealing with a monopolistic competition sector, the profit has to be decreasing in the number of intermediate producers (N). This leads to the restriction $\eta > 1/(1+\alpha)$ that we have explicitly reported in equation (1).

Plugging equation (2) into equation (5), and using the symmetric equilibrium hypothesis, yields the wage rate accruing to one unit of labor employed in the intermediate sector (w_{jt}):

$$w_{jt} = \frac{\alpha}{m} \frac{Y_t}{L_{jt}}. \quad (5')$$

2.2 R&D Sector

There are many competitive research firms undertaking R&D. These firms produce designs indexed by 0 through an upper bound $N \geq 0$. Thus, N_t measures the total stock of society's knowledge at time t . Designs are patented and partially excludable, but non-rival and indispensable for capital goods production. With access to the available stock of knowledge N_t , research firms use labor and develop new blueprints according to the following constant returns to scale R&D technology:

$$\dot{N}_t = \frac{L_{Nt}}{\chi_t} N_t, \quad \chi_t \equiv kL_t, \quad k > 0, \quad (7)$$

where L_N denotes the aggregate employment in research, χ is an index that measures the difficulty of performing R&D activity and k is a parameter.

The χ term in the right-hand side of equation (7) has been introduced first by Dinopoulos and Segerstrom (1999) and captures in a very simple way the idea that R&D difficulty grows with the

size of the market.⁷ The so-called *dilution effect* is at the hearth of equation (7). According to this effect, inventing a new intermediate design requires a labor input equal to χ_t / N_t , which changes over time because of both innovation and population growth. While innovation generates a positive inter-temporal externality, the population growth tends to reduce innovation via a fall in the R&D productivity. The hypothesis that research labor productivity increases with the stock of knowledge (N_t) 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 (see Grossman and Helpman, 1991, Ch. 3; Gancia and Zilibotti, 2005).⁸ The hypothesis that research labor productivity falls with the level of R&D difficulty (χ), instead, can be justified by the idea that it is harder to introduce successfully new varieties and replace older ones when markets are very crowded (Dinopoulos and Segerstrom, 1999).

By defining the growth rate in the number of varieties (i.e. the rate of innovation) at time t by g_{N_t} , yields:

$$g_{N_t} \equiv \frac{\dot{N}_t}{N_t} = \frac{s_{N_t}}{k}, \quad s_{N_t} \equiv \frac{L_{N_t}}{L_t}.$$

Since the research sector is perfectly competitive, the price of the j -th design at time t is 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:

$$P_{N_t} = \int_t^{\infty} \pi_{\tau} e^{-r(\tau-t)} d\tau = \alpha \left(1 - \frac{1}{m}\right) \int_t^{\infty} \frac{Y_{\tau}}{N_{\tau}} e^{-r(\tau-t)} d\tau, \quad \tau > t. \quad (8)$$

In this expression, P_N is the price of the generic j -th blueprint (the one that allows producing the j -th variety of capital goods), π is the profit of the j -th intermediate firm and r is the real interest rate. The fact that in equation (8) an infinite horizon is explicitly considered depends on

⁷ The addition of this variable stems from the Jones (1995) criticism of the scale effect, according to which in the basic Schumpeterian growth literature the steady-state growth rate of the economy tends to explode in the presence of growing population. For a deeper discussion of this issue see, among others, the surveys by Dinopoulos and Thompson (1999), Dinopoulos and Sener (2006) and Jones (2005).

⁸ 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 also their magnitude may 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%.

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 peculiarity of horizontal differentiation growth models. It is also easy to see that for P_{Nt} to be positive the restriction $\tau < 1/a$ must be checked (see equation 1 above). Free-entry into R&D sector implies:

$$P_{Nt} = \frac{\lambda_t}{N_t} w_{Nt}, \quad (9)$$

where w_N is the wage rate accruing to one unit of labor employed in the research sector. Equation (9) 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.

The description of the preferences closes the model.

2.3 Consumers

The economy is populated by infinitely-lived agents who derive utility from consumption of final goods and supply labor inelastically. Population (L) grows at the exogenous rate $n > 0$ and is (fully) employed either in manufacturing or R&D. Total output (Y_t) can be only consumed. Hence, denoting by C_t total consumption at time t , we have $Y_t = C_t$. Each member of the population is endowed with a fixed amount of labor that s/he allocates to either production (homogeneous final goods and intermediate inputs) or research activities. By normalizing to unity the supply of labor of each individual in the economy, the total labor supply available at time t is L_t . The representative consumer of this economy also owns assets (a) in the form of ownership claims on firms and maximizes, under constraint, the discounted value of his/her lifetime utility:

$$\left\{ \begin{array}{l} \text{Max}_{\{c_t\}_{t=0}^{\infty}} U_0 = \int_0^{\infty} e^{-\rho t} \log(c_t) dt \\ \text{s.t. :} \\ \dot{a}_t = w_t + r_t a_t - c_t \end{array} \right.$$

The first order conditions of this problem must satisfy the constraint on a , together with the transversality condition:

$$\lim_{t \rightarrow \infty} \lambda_t a_t = 0.$$

Symbols have the following meaning: U_0 and $\log(c_t)$ are, respectively, the inter-temporal and instantaneous utility functions of the representative agent;⁹ c denotes per-capita consumption ($c_t \equiv C_t / L_t$); ρ is the agent's subjective time preference rate; w and ra are his/her labor and interest incomes and λ_t is the co-state variable.

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

$$\frac{\dot{c}_t}{c_t} = r_t - \rho.$$

Since total output can be only consumed, and given our definition of per-capita consumption, the equation above leads to:

$$\frac{\dot{C}_t}{C_t} = \frac{\dot{Y}_t}{Y_t} \equiv g_{Y_t} = r_t - (\rho - n), \quad \rho > n.^{10} \quad (10)$$

In the model savings are used to finance innovative investments. Moreover, in the BGP equilibrium, when the growth rate of output (g_Y) is constant, r turns out to be constant as well.

3. BGP EQUILIBRIUM

Before characterizing the BGP equilibrium of the model presented so far, we first introduce a formal definition of it.

Definition: A BGP equilibrium is an equilibrium where: (i) The growth rate of all variables depending on time is constant; (ii) The demand for labor coming from each sector (L_Y , L_j and L_N) grows at the same rate as the total supply of labor (L).

⁹ Following Grossman and Helpman (1991) we assume that the instantaneous utility function is logarithmic. Using more general isoelastic functions does not alter the results.

¹⁰ This condition guarantees that the inter-temporal utility function of the representative *household* does not explode.

In order to determine the optimal allocation of the given supply of labor (L_t) across the three sectors using this factor input, we equalize the sectoral wage rates accrued by one unit of labor (this is a homogeneous input and perfectly mobile across sectors and, then, it must be compensated according to a unique wage rate). As a result, the following three conditions must be simultaneously checked:

$$s_{jt} + s_{Yt} + s_{Nt} = 1, \quad \forall t; \quad (11)$$

$$w_{Yt} = w_{jt} \quad (12)$$

$$w_{Yt} = w_{Nt}, \quad (13)$$

where s_{jt} , s_{Yt} and s_{Nt} represent the shares of the total labor supply devoted, respectively, to intermediate and consumption goods production and to research activity.

Equation (11) is the labor market clearing condition, saying that at any point in time total labor demand (the left hand side) must be equal to total labor supply (the right hand side). Equations (12) and (13) together state that the wage earned by one unit of labor is to be the same irrespective of the sector where that unit of labor is actually employed.

The simultaneous resolution of the equations system (11) through (13) yields the following BGP equilibrium values for the relevant endogenous variables of the model (see the Appendix for analytical details):

$$s_N = \alpha(1 - \eta\alpha) - k(\rho - n)(\eta\alpha^2 - \alpha + 1); \quad (14)$$

$$s_Y = (1 - \alpha)[1 + k(\rho - n)]; \quad (15)$$

$$s_j = \eta\alpha^2[1 + k(\rho - n)]; \quad (16)$$

$$g_N \equiv \frac{\dot{N}_t}{N_t} = \frac{\alpha}{k}(1 - \eta\alpha) - (\rho - n)(\eta\alpha^2 - \alpha + 1); \quad (17)$$

$$g_Y \equiv \frac{\dot{Y}_t}{Y_t} = n + \left(\frac{1 - \eta\alpha}{\eta} \left[\frac{\alpha}{k}(1 - \eta\alpha) - (\rho - n)(\eta\alpha^2 - \alpha + 1) \right] \right); \quad (18)$$

$$r = \left(\frac{1 - \eta\alpha}{\eta} \left[\frac{\alpha}{k}(1 - \eta\alpha) - (\rho - n)(\eta\alpha^2 - \alpha + 1) \right] \right) + \rho. \quad (19)$$

Equations (14) through (16) give the (constant) shares of labor supply that are devoted to research, final output and intermediate sectors along the symmetric BGP equilibrium. Equations (17) through (19), instead, represent respectively the equilibrium innovation, output growth and real interest rates. Economic growth (18) does not display any scale effect and turns out to be a function, among others, of the parameter that determines the elasticity of substitution between intermediate inputs, σ , and the labor share in income, $1 - \alpha$. In the next section, we clarify what it means in terms of competition and discuss the main predictions of the model concerning the long-run relationship between PMC and growth.

4. THE RELATIONSHIP BETWEEN PMC AND GROWTH

We now study the long-run relationship between competition and growth in the model presented above. But, before doing this, we first clarify what we mean by competition in the context we are analyzing. Because PMC cannot be measured directly, we necessitate some *proxy* for this variable. The IO literature (both empirical and theoretical) generally uses the so-called *Lerner index* to gauge the intensity of market power within a market. Such index equals the ratio of price (P) minus marginal costs (MC) over price. Given the definition of markup (price to marginal costs), the Lerner index can be re-written as:

$$\text{Lerner index} = (P - MC)/P = 1 - 1/m, \quad m = P/MC.$$

From the last equation it is straightforward to conclude that:

$$1 - \text{Lerner index} = 1/m = \alpha_i.$$

In the remainder of the paper we take (*1-Lerner index*) as a measure of the degree of competition in the intermediate sector.¹¹ Observe that the markup is lower when the elasticity of substitution between each pair of intermediates is higher, that is when both σ and α are higher.¹²

¹¹ This is the same measure of competition used by Aghion *et al.* (2005).

¹² Koeniger and Licandro (2006) have recently cast some doubts on the use of the elasticity of substitution between goods as an indicator for PMC. Their argument hinges on the fact that a change in substitutability also implies a *reallocation effect*. Accordingly, the impact on growth of variations in the degree of competition is overstated when those variations are caught by changes in substitutability. However, their framework only provides a formal analysis

This having been said, PMC may play an important role in economic growth in two fundamental respects. First of all, it allows allocating the available resources to the best uses (*resource allocation effect*), while improving the performance of labor markets (Blanchard, 2004). At the same time, and according to *Schumpeterian* growth theory, because it erodes monopoly rents, PMC is detrimental to innovation (*profit incentive effect*). Equations (8) and (9) can be used to highlight these two effects. A change in m , for given N and for given sectoral distribution of the labor input (L_Y and L_J),¹³ determines a variation in P_N and, thus, in the incentives for firms to perform R&D activity. This is the traditional *profit incentive effect* one may find in most of the R&D-based growth models. In addition, another effect needs to be considered. For given N , the original change in m determines also, through P_N , a variation of the wage rate w (the same across sectors in equilibrium) for equation (9) to hold. The joint variation of m , P_N and w will induce some substitution between intermediate goods and labor in the final output sector and will give rise to a re-allocation of the entire available supply of the labor input in the economy (thereby influencing both L_N and the equilibrium growth rate). Due to the specific assumptions made (namely *Dixit-Stiglitz* technology in the downstream sector and no strategic interaction between intermediate firms), in the model of the previous sections these two effects of PMC on growth (respectively the *resource allocation* and the *profit incentive effects*) are closely related to each other, since more competition in the product market influences firms' profits and incentives to innovate and, thus, modifies both the distribution of labor across economic activities and economic growth.

The originality of this paper lies in the fact that the markup depends on two different components (see equation 5): the input shares in income ($\alpha \equiv ShK=1-ShL$) and the parameter of substitution between intermediates (ι). In the rest of this section we show that results concerning the relationship between PMC and growth may dramatically change depending on which one of these two variables we use as a proxy of competition in the market for intermediates. At this aim we consider two different cases.

for the case of static, price-setting oligopoly. In our paper we just rely on the case of monopolistic competition in a dynamic context.

¹³ In a symmetric equilibrium the level of output is equal to: $Y_t = (L_{Yt})^{1-\alpha} (L_{Jt})^\alpha (N_t)^{(1-\eta\alpha)/\eta}$.

CASE 1: $\iota = 1$.

In the first case we set $\iota = 1$ (as in Romer, 1990) and study the BGP equilibrium relationship between α and g_Y . In this case the main variables of the model become:

$$s_N = \alpha(1-\alpha) - k(\rho - n)(\alpha^2 - \alpha + 1); \quad (14')$$

$$s_Y = (1-\alpha)[1 + k(\rho - n)]; \quad (15')$$

$$s_j = \alpha^2[1 + k(\rho - n)]; \quad (16')$$

$$g_Y \equiv \frac{\dot{Y}_t}{Y_t} = n + (1-\alpha) \left[\frac{\alpha}{k} (1-\alpha) - (\rho - n)(\alpha^2 - \alpha + 1) \right]. \quad (18')$$

Making the assumption of $\iota = 1$ has the implication that variations in the markup and variations in the factor input (labor and capital) income shares are strictly and univocally related to each other. However, this is not a novelty in recent economic theory literature. Following Hall (1988) and Galí (1995), other papers that measure the aggregate markup as a function of the input shares in income in monopolistic competition settings include Neiss (2001), Cavelaars (2003) and Przybyla and Roma (2005).¹⁴ Moreover, Galí and Gertler (1999) have used the labor share as a measure of marginal costs in New Keynesian Phillips curves.

Our model predicts that changes in the factor shares over time and/or across countries should not only have a bearing on the markup, but, through this channel, also on economic growth (see 18' above). Accordingly, the question arises of whether those shares are really stable or not. In this respect, empirical evidence (Galí, 1995, pp.58-60 and, more recently, Bentolila and Saint-Paul, 2003 and Jones, 2003) points to the presence of substantial differences both across countries and over time in the shares of labor and capital in income. As far as the labor share is concerned, Table 1 reports the medium-run movements in that share over a period of 20 years across 12 selected OECD countries.

¹⁴ Galí (1995), Neiss (2001), Cavelaars (2003) and Przybyla and Roma (2005) consider a two-sector framework in which the competitive consumption goods sector employs just differentiated intermediates, and labor is used only by capital goods firms operating in a monopolistically competitive sector. Simply by using the first order conditions for profit maximization of a representative uncompetitive firm, it is shown (see Galí, 1995, p.56; Neiss, 2001, p.574; Cavelaars, 2003, p.87) that the equilibrium markup is equal to the elasticity of output with respect to employment divided by the labor share in income. In the simplest case where the production function of intermediate goods is one-to-one in labor (so that the elasticity of output with respect to employment equals one), the markup turns out to be the inverse of the labor income share (see Blanchard and Giavazzi, 2001). This approach has been used to

The table suggests that the labor share is subject to large movements both cross-country and over time and that, contrary to economists' conjecture, it is not constant. For instance, we see that in 1990 some countries (like Finland or Sweden) had labor shares around 72%, while others (like France, Germany or Italy) showed values around 62%.¹⁵ Moreover, we notice that over twenty years (1970-1990) there has not been any tendency of the labor share to converge across countries (the standard deviation has actually increased in the period analyzed). This is clear evidence that the labor share is definitely not constant. As for the capital share, Jones (2003) comes to a similar conclusion.¹⁶

	Labor Share (in levels)			
	1970	1980	1990	Changes (1970-1990)
United States	69.7	68.3	66.5	-3.2
Canada	66.9	62.0	64.9	-2.0
Japan	57.5	69.1	68.0	10.5
Germany	64.1	68.7	62.1	-2.0
France	67.6	71.7	62.4	-5.2
Italy	67.1	64.0	62.6	-4.4
Australia	64.8	65.9	62.9	-1.9
Netherlands	68.0	69.5	59.2	-8.8
Belgium	61.6	71.6	64.0	2.4
Norway	68.4	66.4	63.9	-4.5
Sweden	69.7	73.6	72.6	2.9
Finland	68.6	69.6	72.3	3.7
<i>Mean</i>	66.2	68.4	65.1	-1.1

construct time series for the economy-wide markup and to analyze, among other things, its cyclical behavior (Rotemberg and Woodford, 1999).

¹⁵ Gali (1995), pp.58, reports that in 1985 many African countries had labor shares around or below 20% (19.8% for Benin; 19% for Burundi; 20.2% for Malawi; 17,6% for Niger; 21,9% for Nigeria; 18% for Sierra Leone and 14.1% for Tanzania).

¹⁶ In particular, he concludes: “Overall, both the country-level and the industry-level evidence - in this paper and in other papers - sharply call into question the stylized fact that capital shares are smooth, stable, and do not exhibit medium-run trends. This fact is roughly true for some countries, but it is strongly contradicted in others. Even in the United States, a country typically used to justify the stylized fact, the industry-level evidence suggests there are substantial changes in capital shares over time” (Jones, 2003, pp.7-10).

<i>Standard Deviation</i>	3.6	3.3	4.1	0.5
---------------------------	-----	-----	-----	-----

Table 1: *The labor share in 12 OECD countries over time (1970-1990).* Source: Bentolila and Saint-Paul (2003). Note: All variables in percentage. The data reported by the table include an imputed labor remuneration for the self-employed on the basis of the average wage.¹⁷ The labor share corresponds to the business sector.¹⁸

Turning back to our model, when we plot equation (18') against the inverse of the markup ($\alpha \equiv ShK = 1 - ShL$) we obtain the following Figure:

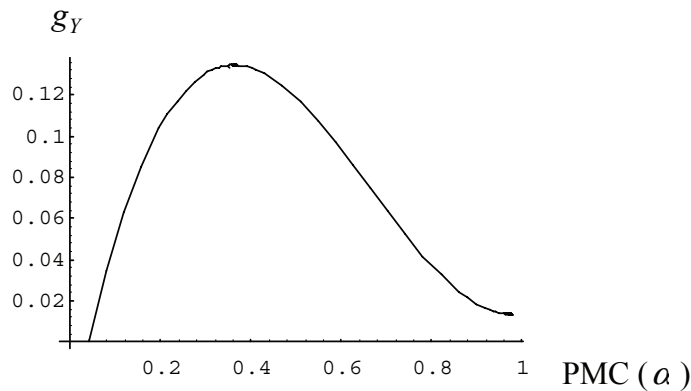


FIGURE 1: *The relationship between PMC (α) and growth (g_Y) when $\tau = 1$*

In drawing Figure 1 we used the following parameter values: $k=1$, $n=0.0144$ ¹⁹ and $\rho=0.07$.²⁰

Figure 1 suggests that there exists a *bell-shaped* relationship between competition and growth

¹⁷ Checchi and Garcia-Penalosa (2005) compute the labor share for 16 OECD countries over the period 1960-96 as the ratio between “compensation per employees and GDP” without including the self-employed workers. On average they obtain that the labor share has been around 52%.

¹⁸ The business sector data stop in 1998. Evidence from individual countries for which data have been continuously available shows little change in the labor share since 1998 (Blanchard and Giavazzi, 2003, p. 903).

¹⁹ Jones and Williams (2000), p.73, Table 1.

²⁰ Mehra and Prescott (1985) report that the average real return on the stock market for the previous century was of 0.07. Jones and Williams (2000, p.73, Table 1) consider interest rates ranging from 0.04 to 0.14, representing one-half and twice the value of 0.07. When ρ takes on values around this range the behavior of g_Y , as a function of α , does not change qualitatively.

when PMC is measured by the capital share in income.²¹ This is the same result recently obtained by Aghion *et al.* (2005) in a vertical differentiation setting. But, unlike that paper (where the *escape competition* and *Schumpeterian effects* play a major role), we can explain the inverted-*U* relationship between competition and growth in terms of the interaction between the *profit incentive* and *resource allocation effects* highlighted above.

Suppose, as in our model, that labor is directly employed in each economic activity. At low initial levels of α , an increase of competition, by lowering the price of capital goods for given marginal cost, reduces the share of labor devoted to final output manufacturing, s_Y (equation 15') and the resources released by this sector can be allocated both to the production of durables (s_j) and research (s_N) – see equations 16' and 14'.

In Figure 1 we see that for values of α lower than a threshold level, this positive *resource allocation effect* outweighs the *profit incentive effect* (the negative effect of more competition on innovation) and the relationship between PMC and growth may be positive. At higher levels of α , instead, a further increase of PMC reduces the share of labor devoted to final output manufacturing (s_Y) and to research (s_N), while continuing to increase s_j . In other words, with α large enough, additional increases of competition imply more capital goods production and a higher labor demand coming from the intermediate sector.²² However, unlike what happens for low levels of α , now the supplementary resources requested for the production of durables are drawn not only from the downstream sector, but also from research (s_N is lower). In Figure 1 it is clear that for values of α greater than a given threshold level, PMC and growth are negatively correlated, meaning that in this interval both the *profit incentive effect* and the *resource allocation effect* are negative and reinforce each other.

²¹ The function $g_Y(\alpha)$ maintains the same graphical behavior even if we restrict our attention to values of α strictly between 0.264 and 0.425. These two values are obtained by considering the lowest and the highest labor share in Table 1 (respectively, 57.5% for Japan in 1970 and 73.6% for Sweden in 1980) and computing (1-73.6%) as the lower-bound and (1-57.5%) as the upper-bound limits of α . Note that a value of $\alpha \cong 1/3$ (generally employed in empirical and theoretical analyses on growth) is exactly in between 0.264 and 0.425.

²² Recall that durables are produced one-to-one with labor.

CASE 2: $0 < \frac{1}{1+\alpha} < \eta < \frac{1}{\alpha}, \quad \eta \neq 1.$

We now consider the (more general) case of $0 < \frac{1}{1+\alpha} < \eta < \frac{1}{\alpha}$, with $\eta \neq 1$ and focus on it as a proxy of PMC. In plotting equation (18) against η , first of all we have to determine its range of variation. Observe that in the case we are considering such a range depends on α . To the best of our knowledge, there are no empirical estimates of the elasticity of substitution between intermediate goods in Dixit-Stiglitz technologies. Accordingly, we proceed as follows. Firstly, we fix the labor share ($ShL \equiv 1 - \alpha$) to 0.64 (see Jones and Williams, 2000, p. 73, Table 1). This value is close to the average of the labor shares in 1990 for the 12 countries considered in table 1. Next, we know from the empirical industry-level estimates by Norrbin (1993) and Basu (1996) that the markup -- $m \equiv 1/\eta (1 - ShL)$ in our case -- is approximately between 1.05 and 1.4. Thus, with a labor share of 0.64, this suggests focusing on an interval of η ranging between 1.98 and 2.65. Note that when the markup is constrained to be between 1.05 and 1.4, the restriction $0 < 1/(1+\alpha) < \eta < 1/\alpha$ is still checked. The results are in Figure 2. In drawing Figure 2 we continue to use the parameter values: $k=1, n=0.0144$ and $\rho=0.07$:

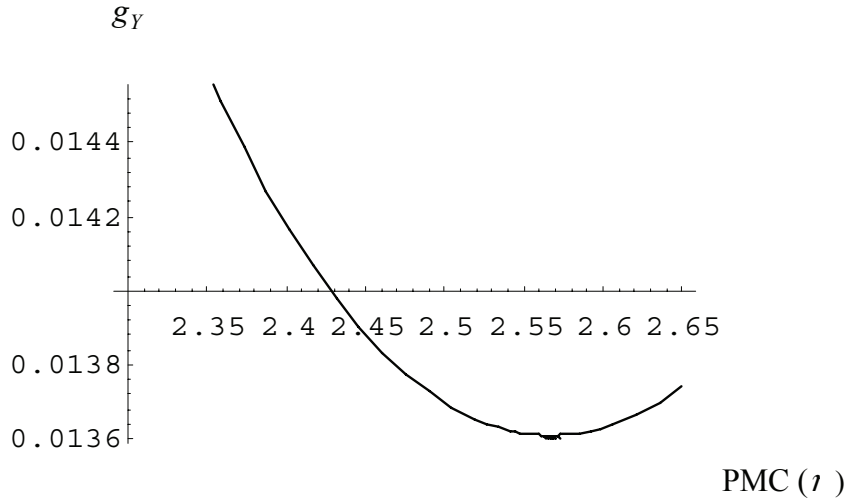


FIGURE 2: *The relationship between product market competition (η) and growth (g_Y) under constrained markups ($1.05 < m < 1.4$)*

Observe that Figure 2 presents a minimum. This result crucially depends on the magnitude of the labor share $(1-\alpha)$. In general, the larger is the labor share, the more likely is the existence of the minimum between the corresponding range of γ . Even when we use a labor share of 0.52 (i.e. a share that excludes the self-employed workers - see Checchi and Garcia-Penalosa, 2005), we continue to find a minimum in the range $0 < 1/(1+\alpha) < \gamma < 1/\alpha$.

Again, the *resource allocation* and *profit incentive effects* can be used to explain the intuition behind the shape of the relationship between competition (γ) and growth (g_Y) in Figure 2. In a symmetric BGP equilibrium the level of output is equal to:

$$Y_t = (s_Y)^{1-\alpha} (s_j)^\alpha (N_t)^{\frac{1-\eta\alpha}{\eta}} L_t.$$

This means that, for given s_Y (independent of γ) and L_t (that evolves exogenously over time), the contribution to aggregate output (Y) following a change of γ can come from variations in s_j and N . According to the *profit-incentive-effect*, a higher elasticity of substitution (a higher γ , for given α) reduces the monopoly power of intermediate producers and, thus, their profits. This implies that now innovation pays less (*ceteris paribus*, the market value of a single idea decreases, see equation 8), which leads to a lower firms' incentive to innovate (a lower N) and, in turn, to lower economic growth (Y decreases). Therefore, the profit incentive effect predicts an unambiguously negative relationship between PMC (γ) and growth. At the same time, however, and according to the *resource allocation effect*, a higher elasticity of substitution (a higher γ , for given α), by increasing the degree of PMC in the intermediate sector leads the representative firm of this industry to produce more output at a lower gross markup. Hence, the demand for labor coming from the intermediate sector (s_j) rises and so does economic growth, too (Y increases). Hence, the resource allocation effect points to a positive relationship between PMC (γ) and growth. Having this in mind, Figure 2 suggests that the negative effect of an increase of competition on growth (the *profit incentive effect*) prevails over the positive one (the *resource allocation effect*) at low levels of competition, whereas the inverse is true for a sufficiently higher degree of competition (in this case it is the *resource allocation effect* to outweigh the *profit incentive effect*). This might help explaining the U-shaped relationship between PMC and aggregate economic growth when competition is measured by the parameter of substitutability between intermediate inputs.

5. CONCLUDING REMARKS

In this paper we analyzed the relationship between competition and growth in a model of ever-expanding product varieties without scale effects. More specifically, we purged the scale effect by means of the so-called *dilution hypothesis* and focused on two alternative measures of PMC (namely the factor input income shares, on the one hand, and the parameter determining the elasticity of substitution between intermediate inputs, on the other).

We found that it is possible to restore an inverse U-shaped relationship between competition and growth in the baseline Romer's (1990) model simply by introducing the assumption that a fixed-supply input is used in each economic sector. However, as soon as we allow for the parameter determining the elasticity of substitution between intermediate products to be different from one (so moving to the diverse proxy of PMC proposed by Jones and Williams, 2000), we find that the relationship between competition and growth overturns.

Clearly, more work is needed to resolve the theoretical ambiguities concerning the effect of PMC on economic growth and to come to more definitive conclusions on this topic. Accordingly, for future research it would be interesting to study how results might change in the presence of alternative ways of cleaning the scale effect prediction from the model, as well as they might depend on the distance of a country from the technological frontier, the availability of human capital, and other initial conditions.

REFERENCES

- Aghion, P., Bloom, N., Blundell, R., Griffith, R. and P. Howitt (2005), "Competition and Innovation: An Inverted-U Relationship", *Quarterly Journal of Economics*, 120(2), 701-28.
- Aghion, P., Dewatripont, M. and P. Rey (1997), "Corporate Governance, Competition Policy and Industrial Policy", *European Economic Review*, 41(3-5), 797-805.
- Aghion, P., Dewatripont, M. and P. Rey (1999), "Competition, Financial Discipline, and Growth", *Review of Economic Studies*, 66(4), 825-52.
- Aghion, P. and R. Griffith (2005), *Competition and Growth: Reconciling Theory and Evidence*, Cambridge, MA: MIT Press.

- Aghion, P., Harris, C., Howitt, P. and J. Vickers (2001), "Competition, Imitation, and Growth with Step-by-Step Innovation", *Review of Economic Studies*, 68(3), 467-92.
- Aghion, P., Harris, C. and J. Vickers (1997), "Competition and Growth with Step-by-Step Innovation: An Example", *European Economic Review*, 41(3-5), 771-82.
- Aghion, P. and P. Howitt (1992), "A Model of Growth Through Creative Destruction", *Econometrica*, 60(2), 323-51.
- Aghion, P. and P. Howitt (1996), "Research and Development in the Growth Process", *Journal of Economic Growth*, 1(1), 49-73.
- Aghion, P. and P. Howitt (1998a), *Endogenous Growth Theory*, Cambridge, MA: MIT Press.
- Aghion, P. and P. Howitt (1998b), "Market Structure and the Growth Process", *Review of Economic Dynamics*, 1(1), 276-305.
- Aghion, P. and P. Howitt (2005), "Growth with Quality-Improving Innovations: An Integrated Framework", in P. Aghion and S. Durlauf (ed.), *Handbook of Economic Growth*, Volume 1, Part 1, Chapter 2, pp. 67-110, Amsterdam: Elsevier Science, North Holland.
- Ahn, S. (2002), "Competition, Innovation and Productivity Growth: A Review of Theory and Evidence", *OECD Economics Department Working Paper n.2002/3*.
- Basu, S. (1996), "Procyclical Productivity: Increasing Returns or Cyclical Utilization?," *Quarterly Journal of Economics*, 111(3), 719-51.
- Bentolila, S. and G. Saint-Paul (2003), "Explaining Movements in the Labor Share", *Contributions to Macroeconomics*, 3(1), Article 9.
- Blanchard, O. (2004), "The economic future of Europe", *Journal of Economic Perspectives*, 18(4), 3-26.
- Blanchard, O. and F. Giavazzi (2001), "Macroeconomic effects of regulation and deregulation in goods and labor markets", *NBER Working Paper n.8120*.
- Blanchard, O. and F. Giavazzi (2003), "Macroeconomic effects of regulation and deregulation in goods and labor markets", *Quarterly Journal of Economics*, 118(3), 879-907.
- Blundell, R., Griffith, R. and J. van Reenen (1999), "Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms", *Review of Economic Studies*, 66(3), 529-54.
- Bucci, A. (2003), "Market Power and Aggregate Economic Growth in Models with Endogenous Technological Change", *Giornale degli Economisti e Annali di Economia*, 62(2), 241-91.
- Caballero, R.J. and A.B. Jaffe (1993), "How High Are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth", in O.J. Blanchard and S. Fischer, eds., *NBER Macroeconomics Annual*, pp. 15-74, Cambridge and London: MIT Press.
- Cavelaars, P. (2003), "Does Competition Enhancement Have Permanent Inflation Effects?," *Kyklos*, 56(1), 69-94.
- Cecchi, D. and C. García-Peñalosa (2005), "Labour market institutions and the personal distribution of income in the OECD", *CESIFO Working Paper n. 1608*.
- Cohen, W.M. (1995), "Empirical Studies of Innovative Activity", in P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Change*, Oxford: Basil Blackwell.
- Cohen, W.M. and R.C. Levin (1989), "Empirical Studies of Innovation and Market Structure", in R. Schmalensee and R.D. Willig (eds.), *Handbook of Industrial Organization*, Vol. II, Amsterdam: Elsevier Science, North Holland, 1059-1107.
- Dasgupta, P. and J. Stiglitz (1980), "Industrial Structure and the Nature of Innovative Activity", *Economic Journal*, 90(358), 266-93.

- Dinopoulos, E. and P. Segerstrom (1999), "A Schumpeterian Model of Protection and Relative Wages", *American Economic Review*, 89(3), 450-72.
- Dinopoulos, E. and F. Sener (2006), "New Directions in Schumpeterian Growth Theory", in H. Hanusch and A. Pyka (eds.), *Edgar Companion to Neo-Schumpeterian Economics*, Cheltenham, UK: Edward Elgar.
- Dinopoulos, E. and P. Thompson (1999), "Scale Effects in Schumpeterian Models of Economic Growth", *Journal of Evolutionary Economics*, 9(2), 157-85.
- Dixit, A. K. and J.E. Stiglitz (1977), "Monopolistic Competition and Optimum Product Diversity", *American Economic Review* 67(3), 297-308.
- Ethier, W. J. (1982), "National and International Returns to Scale in the Modern Theory of International Trade", *American Economic Review* 72(3), 389-405.
- Gali, J. (1995), "Product diversity, endogenous markups, and development traps", *Journal of Monetary Economics*, 36(1), 39-63.
- Gali, J. and M. Gertler (1999), "Inflation Dynamics: A Structural Econometric Analysis", *Journal of Monetary Economics*, 44(2), 195-222.
- Gancia, G. and F. Zilibotti (2005), "Horizontal Innovation in the Theory of Growth and Development", in P. Aghion and S. Durlauf (ed.), *Handbook of Economic Growth*, Volume 1, Part 1, Chapter 3, pp. 111-170, Amsterdam: Elsevier Science, North Holland.
- Geroski, P. (1994), *Market Structure, Corporate Performance and Innovative Activity*, Oxford: Oxford University Press.
- Griliches, Z. (1992), "The Search for R&D Spillovers", *Scandinavian Journal of Economics* 94(0), *Supplement*, S29-47.
- Grossman, G.M. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, MA: MIT Press.
- Hall, R.E. (1988), "The relation between price and marginal cost in the U.S. industry", *Journal of Political Economy*, 96(5), 921-47.
- Jones, C. I. (1995), "R&D-Based Models of Economic Growth", *Journal of Political Economy*, 103(4), 759-84.
- Jones, C.I. (2003), "Growth, Capital Shares, and a New Perspective on Production Functions", *University of Berkeley, mimeo*. <http://elsa.berkeley.edu/~chad/alpha100.pdf>
- Jones, C.I. (2005), "Growth and Ideas", in P. Aghion and S. Durlauf (ed.), *Handbook of Economic Growth*, Volume 1, Part 2, Chapter 16, pp. 1063-1111, Amsterdam: Elsevier Science, North Holland.
- Jones, C.I. and J.C. Williams (2000), "Too Much of a Good Thing? The Economics of Investment in R&D", *Journal of Economic Growth*, 5(1), 65-85.
- Klette, T. J., J. Moen and Z. Griliches (2000), "Do Subsidies to Commercial R&D Reduce Market Failures? Microeconomic Evaluation Studies", *Research Policy*, 29(4-5), 471-95.
- Koeniger, W. and O. Licandro (2006), "On the Use of Substitutability as a Measure of Competition", *Topics in Macroeconomics*, 6(1), Article 2.
- Levin, R.C., Cohen, W.M. and D.C. Mowery (1985), "R&D Appropriability, Opportunity and Market Structure: New Evidence on Some Schumpeterian Hypotheses", *American Economic Review, Papers and Proceedings*, 75(2), 20-4.
- Mehra, R. and E.C. Prescott (1985), "The Equity Premium: A Puzzle", *Journal of Monetary Economics*, 15(2), 145-61.
- Nadiri, I.M. (1993), "Innovations and Technological Spillovers", *NBER Working Paper n.4423*.

- Neiss, K.S. (2001), "The markup and inflation: evidence in OECD countries", *Canadian Journal of Economics*, 34(2), 570-87.
- Nickell, S.J. (1996), "Competition and Corporate Performance", *Journal of Political Economy*, 104(4), 724-46.
- Norrbin, S.C. (1993), "The Relationship between Price and Marginal Cost in U.S. Industry: A Contradiction," *Journal of Political Economy*, 101(6), 1149-64.
- Przybyla, M. and M. Roma (2005), "Does product market competition reduce inflation? Evidence from EU countries and sectors", *European Central Bank Working Paper n.453*.
- Romer, P. M. (1990), "Endogenous Technological Change", *Journal of Political Economy*, 98(5), *Supplement*, S71-102, Part 2.
- Rotemberg, J.J. and M. Woodford (1999), "The Cyclical Behavior of Prices and Costs", in J.B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, Vol. 1B, Amsterdam: Elsevier Science, North Holland, 1051-1135.
- Scherer, F.M. (1965), "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions", *American Economic Review*, 55, 1097-1125.
- Scherer, F.M. (1967), "Market Structure and the Employment of Scientists and Engineers", *American Economic Review*, 57, 524-31.
- Scherer, F.M. (1992), "Schumpeter and Plausible Capitalism", *Journal of Economic Literature*, 30(3), 1416-33.
- Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, New York: Harper and Row.
- Scott, J.T. (1984), "Firm versus Industry Variability in R&D Intensity", in Z. Griliches (ed.), *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, 233-45.
- Smulders, S. and T. van de Klundert (1995), "Imperfect competition, concentration and growth with firm-specific R&D", *European Economic Review*, 39(1), 139-160.
- Spence, M. (1976), "Product Selection, Fixed Costs, and Monopolistic Competition", *Review of Economic Studies*, 43(2), 217-35.
- Symeonidis, G. (1996), "Innovation, Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes", *OECD Economic Studies*, 0(27), 35-70.
- van Cayseele, P.J.G. (1998), "Market Structure and Innovation: A Survey of the Last Twenty Years", *De Economist*, 146(3), 391-417.
- van de Klundert, T. and S. Smulders (1997), "Growth, Competition and Welfare", *Scandinavian Journal of Economics*, 99(1), 99-118.

APPENDIX

In this Appendix we derive the set of results (14) through (19) in the main text.

In the BGP equilibrium $g_Y \equiv \dot{Y}_t/Y_t$, $g_N \equiv \dot{N}_t/N_t$ and r are constant. Using equation (8) in the main text this implies:

$$(A1) \quad P_{N_t} = \frac{\alpha}{g_N - g_Y + r} \left(1 - \frac{1}{m}\right) \frac{Y_t}{N_t}.$$

From the free-entry condition in the main text (equation 9) we obtain:

$$(A2) \quad w_{N_t} = \frac{\alpha}{g_N - g_Y + r} \left(1 - \frac{1}{m}\right) \frac{Y_t}{\chi_t}.$$

Equating (3) and (5') in the main text yields:

$$s_{j_t} = \frac{\alpha}{m(1-\alpha)} s_{Y_t},$$

whereas, equating (3) and (A2) above one obtains:

$$s_{Y_t} = \frac{k(1-\alpha)(g_N - g_Y + r)}{\alpha \left(1 - \frac{1}{m}\right)}.$$

Since $r = \rho + g_Y - n$ (see equation 10 in the main text) and $g_{N_t} \equiv \frac{\dot{N}_t}{N_t} = \frac{s_{N_t}}{k}$, s_{Y_t} can also be

written as:

$$s_{Y_t} = \frac{(1-\alpha)[s_{N_t} + k(\rho - n)]}{\alpha \left(1 - \frac{1}{m}\right)}.$$

Accordingly, s_{j_t} becomes:

$$s_{j_t} = \frac{[s_{N_t} + k(\rho - n)]}{(m-1)}.$$

Using (11) in the main text and the fact that $m \equiv 1/\eta\alpha$ we conclude that:

$$s_{N_t} = \alpha(1-\eta\alpha) - k(\rho - n)(\eta\alpha^2 - \alpha + 1) = s_N.$$

Given s_N we may easily obtain:

$$s_{Y_t} = (1-\alpha)[1 + k(\rho - n)] = s_Y;$$

$$s_{j_t} = \eta\alpha^2 [1 + k(\rho - n)] = s_j;$$

$$g_{N_t} \equiv \frac{\dot{N}_t}{N_t} = \frac{s_{N_t}}{k} = \frac{\alpha}{k} (1-\eta\alpha) - (\rho - n)(\eta\alpha^2 - \alpha + 1) = g_N.$$

In a symmetric BGP equilibrium, the level of GDP at t is:

$$Y_t = (L_{Yt})^{1-\alpha} (L_{jt})^\alpha (N_t)^{\frac{1-\eta\alpha}{\eta}},$$

and its growth rate (g_Y) is:

$$g_{Yt} \equiv \frac{\dot{Y}_t}{Y_t} = n + \left(\frac{1-\eta\alpha}{\eta} \right) \left[\frac{\alpha}{k} (1-\eta\alpha) - (\rho - n)(\eta\alpha^2 - \alpha + 1) \right] = g_Y,$$

where n is the exogenous population growth.

Given g_Y , the real interest rate is (equation 10 in the main text):

$$r_t = g_{Yt} + \rho - n = \left(\frac{1-\eta\alpha}{\eta} \right) \left[\frac{\alpha}{k} (1-\eta\alpha) - (\rho - n)(\eta\alpha^2 - \alpha + 1) \right] + \rho = r.$$

Notice that:

$$g_N - g_Y + r = \alpha(1-\eta\alpha) \left[\frac{1}{k} + (\rho - n) \right].$$

With $\alpha \in (0,1)$, $\eta < 1/\alpha$, $k > 0$ and $\rho > n$, the sum written above is always positive. This ensures that $P_{Nt} > 0$ for each t (see equation A1 above).