Competition and growth in a neo-Schumpeterian model

Vincenzo Denicolò*
Dipartimento di Scienze Economiche, Università di Bologna, Italy
and
Piercarlo Zanchettin
School of Economics, University of Nottingham, UK

Abstract

We re-consider the relationship between competition and growth in a standard neo-Shumpeterian model with improvements in the quality of products. We focus on the case of non-drastic innovations, and we model the notion of lower competition by a switch from Bertrand to Cournot competition. Our main finding is that when the size of innovations is sufficiently large, the equilibrium rate of growth is unambiguously greater with Bertrand than with Cournot competition. For smaller innovation, Cournot competition may (but need not) create greater incentive to innovate (hence greater rates of growth). However, the welfare comparison of the Bertrand and Cournot equilibria is generally ambiguous.

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*Corresponding author: Dipartimento di Scienze Economiche, Piazza Scaravilli 2, I-40125 Bologna, Italy; E-mail: denicolo@economia.unibo.it

1 Introduction

Recent empirical work by Nickell (1996), Blundell, Griffiths and van Reenen (1996) and Aghion et al. (2001) suggests that more competition leads to faster growth by enhancing the speed of technical progress. This contrasts with the conclusions of early models of endogenous growth with quality ladders (see Aghion and Howitt, 1992, Segerstrom, Anant and Dinopoulos, 1990, and Grossman and Helpman, 1991), that predict a negative relation between competition and growth. In these models, at every point in time the only active firms in each industry is the technological leader. Then, it is natural to measure the degree of competition by the inverse of the elasticity of demand, which equals the size of the mark-up that the leader charges when the innovations are drastic.[1]

In this paper we re-consider the relationship between competition and growth by focusing on the case of non-drastic innovations, and parametrizing the degree of competition by a switch from Bertrand to Cournot competition. This allows us to disentangle the effects of a change in the degree of competition from those associated with changes in structural (taste and/or technology) parameters that ultimately determine the elasticity of demand. Another interesting feature of the Cournot equilibrium is that several firms are simultaneously active in each industry.[2]

Our main finding is that when the size of innovations is sufficiently large, the equilibrium rate of growth is unambiguously greater with Bertrand than with Cournot competition. For smaller innovation, Cournot competition may (but need not) create greater incentive to innovate (hence greater rates of growth). The intuition is that more competition entails lower prices but at the same time leads to greater productive efficiency in that it lowers the market share of less productive firms (Aghion and Shankerman, 2000). When firms are symmetric only the first effect is at work and a switch from Cournot to Bertrand competition reduces the industry profits. However, in the presence of intellectual property rights technical progress tends to create asymmetries between firms and thus the productive efficiency effect becomes important. Therefore, the effect of more competition on innovators' profits is generally ambiguous.

[1] An innovation is drastic if the patentee is unconstrained by outside competition and can therefore engage in monopoly pricing.

[2] For a different attempt to develop a model with many firms in each industry see Peretto (1996).

However, the productive efficiency effect must dominate if innovations are close to being drastic. To see this, note that the presence of a less efficient competitor (namely, the holder of the patent on the previous innovation) constrains the technological leader but when innovations are almost drastic the equilibrium price will be just below the monopoly price. As a consequence, in the Bertrand equilibrium the effect of competition on the technological leader's profits is second order. By contrast, with Cournot competition the inefficient firm will hold a positive market share and this has a first order effect on industry profits.

The productive efficiency effect is well known in the industrial organization literature, that has examined the relation between competition and firms' incentive to innovate extensively. While most of the early literature focused on competition in the research sector (see Loury (1979), Lee and Wilde (1980), Dasgupta and Stiglitz (1980)), in the past decade the effects of product market competition have come to the forefront. Delbono and Denicolò (1990) find that Bertrand duopolists have greater incentive to innovate than Cournot duopolists when the product is homogenous; however, Bester and Petrakis (1993) and Bonanno and Haworth (1998) show that this result can be reversed with horizontal and vertical product differentiation, respectively.[3] Boone (2000, 2001) generalizes these findings and shows that the relation between competition and incentives to innovate is generally non monotone. However, all these papers adopt a partial equilibrium framework.

Other papers try to reconcile endogenous growth theory with the empirical evidence on the relationship between competition and growth. Aghion, Harris and Vickers (1997) and Aghion et al. (2001) develop step-by-step general equilibrium models of technical progress in which more competition (as measured by either a greater elasticity of demand or as a switch from Cournot to Bertrand competition) may be beneficial to growth. In step-by-step models, firms' incentive to innovate is greatest when they are neck-and-neck (which can never occur in leapfrogging models). In such a state, the incentive to gain a technological lead is obviously greater under Bertrand competition; however, with Bertrand competition the fraction of industries in which firms are neck-and-neck tends to be lower. Aghion, Dewatripont and Rey (1997, 1999) introduce agency issues into the picture. In their model,

[3] While Delbono and Denicolò (1990) model technical progress as a patent race, as in the endogenous growth literature, Qui (1997) assumes that both duopolists can innovate simultaneously and find that in such a framework the incentive to innovate is greater with Cournot competition even if the product is homogeneous.

non-profit maximizing managers will delay the adoption of new technologies until the profits fall below a threshold level. The effect of more competition is to reduce profits thereby speeding up the adoption process. Finally, in the quality-variety models of van de Klundert and Smulders (1995, 1997), more competition reduces the equilibrium number of varieties and increase the size of active firms, which raises their incentive to innovate.

Our model differs from this literature in that we make no special assumptions: we use the standard leapfrogging model with profit-maximizing firms and a fixed number of varieties. Our main innovation is to develop the analysis under the assumption of Cournot competition; obviously, this analysis is meaningful only if innovations are non-drastic. In this sense, ours is the most economical way to reconcile endogenous growth theory with the empirical evidence on competition and growth. More to substance, the effect of competition on productive efficiency is both theoretically and empirically important, and our analysis incorporates it into a general equilibrium growth model.

The rest of the paper is organised as follows. In section 2, we set up the model, and in section 3 we derive the model equilibrium under Bertrand competition. Section 4 covers new ground by developing the analysis of the case of Cournot competition. Section 5 compares the Bertrand and Cournot equilibria and proves the main result of the paper. The welfare analysis is developed in Section 6. Section 7 offers some concluding remarks.

2 The model

We use a one-sector version of the model of Barro and Sala-i-Martin (1995, ch. 7), but the main results are more general and can be re-produced in many other models with quality improvements.

The economy is populated by identical individuals whose mass is normalized to 1. Each individual has linear intertemporal preferences:

$$u(c) = \int_0^1 c(t)e^{-rt}dt \qquad (1)$$

so that the rate of time preference r coincides with the equilibrium rate of interest. Each individual inelastically offers one unit of labour. The final good y is produced in a perfectly competitive market using labour (which is in fixed supply) and an intermediate good according to the following production function:

$$y_k = \tilde{X}_k^{\alpha}, \; 0 < \alpha < 1, \tag{2}$$

where

$$\tilde{X}_k = \sum_{s=0}^{k} q^s x_s$$

is the quality-adjusted index of a composite good which combines all past generations of intermediate goods.

Technical progress takes the form of an increase in the quality of intermediate goods: $q > 1$ is the size of each innovation and k is the number of past innovations. In what follows we find it useful to re-formulate $\tilde{X}_k$ in the equivalent form

$$\tilde{X}_k = q^k X_k \, , \tag{3}$$

where $X_k = \sum_{s=0}^{k} q^{s-k} x_s$ measures the input of the composite intermediate good in efficiency units relative to the last vintage. We assume that innovations are non-drastic, which in the current setting means that $\alpha q \geq 1$. Independently of its quality, the intermediate good is produced using the final good with a constant marginal rate of transformation that is normalised to 1. The final good may be consumed, used to produce intermediate goods, or used in research.

In a stationary equilibrium the price of the intermediate good will be constant and therefore $\tilde{X}_k$ will grow at rate $q^{\frac{1}{1-\alpha}}$. From (2) it then follows immediately that $\frac{y_{k+1}}{y_k} = q^{\frac{\alpha}{1-\alpha}}$. This is the growth factor between periods (a period is the random time interval between two innovations), and we denote it by $g \equiv q^{\frac{\alpha}{1-\alpha}}$. In a steady state, consumption, the input of intermediate goods (X_k), and R&D investment will all grow at rate g between periods.

Innovative activity happens at a rate determined by R&D efforts. In each period there is a patent race. Research can be conducted by any firm, which is currently active in the product market, or by outsiders. There is free entry by outsiders. Let $n_k = \sum_i n_{ik}$ denote aggregate R&D investment, in units of the consumption good, to obtain the $k+1$-th innovation. The innovation occurs according to a Poisson process with hazard rate $z_k = h_k(n_k)$, where $h_k(n_k)$ is increasing and weakly concave (concavity may reflect the presence of external diseconomies in research). For simplicity, we specify the aggregate hazard function as

$$h_k(n_k) = \lambda_k n_k^{\beta}, \quad 0 < \beta \leq 1, \quad \lambda_k > 0. \tag{4}$$

When $\beta = 1$ one obtains the standard case with constant returns in the R&D sector. When the innovation occurs, the probability of firm i being granted the patent is $\frac{n_{ik}}{n_k}$. The innovator is granted an infinitely lived patent on his innovation. There is perfect patent protection, which means that nobody can imitate the innovation.

In order to guarantee the existence of a steady state with positive growth, following Barro and Sala-i-Martin (1995, p. 250) we assume that

$$\lambda_k = \lambda g^{-\beta k} \tag{5}$$

Under this assumption, in a steady state the hazard rate $z_k = \lambda_k n_k^{\beta}$ will be constant across periods. In a steady state the output of the intermediate good, consumption and R&D investment will all grow at rate g between periods. The expected rate of growth is $z \log g$.

In what follows, we shall assume that the current leader (more generally, any currently active firm) does no research and is therefore systematically replaced by outsiders. As discussed at greater length in Denicolò (2001), this pattern of leapfrogging is indeed an equilibrium of a simultaneous moves R&D game if the size of innovations is not too small. Since our main result applies to the case in which innovations are almost drastic, the leapfrogging assumption is not restrictive.

3 Bertrand competition

In this section we develop the model solution assuming that firms compete in prices. Such a Bertrand equilibrium is standard in the endogenous growth literature. We develop it in some detail in order to get a benchmark to contrast with the Cournot equilibrium to be analysed later.

With Bertrand competition, the latest innovator will be the only active firm in the product market and only the best quality of the intermediate good will be used, so that the production function reduces to

$$y_k = q^{\alpha k} x_k^{\alpha} \tag{6}$$

From the production function (6) one obtains the demand for the latest generation of the intermediate good:

$$x_k = \alpha^{\frac{1}{1-\alpha}} p_k^{-\frac{1}{1-\alpha}} g^k \tag{7}$$

where p_k is its price. The k-th innovator holds a patent covering the k-th intermediate good and will price it so as to maximise its profit $(p_k - 1)x_k$. Because innovations are non-drastic and in a leapfrogging equilibrium the next best quality is available to a firm other than the current leader, the leader is constrained by outside competition. The outcome will be a limit-pricing equilibrium where the leader prices at $p_B = q$ and drives his competitors out of the market.

The corresponding profit is:

$$\pi_k^B = (q - 1)\, q^{-\frac{1}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} g^k \tag{8}$$

or $\pi^B g^k$, where $\pi^B = (q - 1)\, q^{-\frac{1}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}}$.

Next consider the research industry. At equilibrium, outsiders' expected net profit must be equal to zero, i.e.:

$$\lambda_k n_k^{\beta - 1} E(V_{k+1}) = 1 \tag{9}$$

where $E(V_{k+1})$ is the expected value of the k+1-th innovation. Positing that the leader will be displaced by an outsider in the next race, $E(V_{k+1})$ is determined by the following asset condition:

$$rE(V_{k+1}) = \pi^B g^{k+1} - \lambda_{k+1} n_{k+1}^{\beta} E(V_{k+1}) \tag{10}$$

which says that securities issued by the leader pay the flow profit π_{k+1}^B less the expected capital loss $\lambda_{k+1} n_{k+1}^{\beta} E(V_{k+1})$ that will be incurred when the next innovation is achieved (driving the leader's profit to zero). Equation (10) can be solved to get:

$$E(V_{k+1}) = \frac{\pi^B g^{k+1}}{r + \lambda_{k+1} n_{k+1}^{\beta}}. \tag{11}$$

Assumption (5) implies that in a steady state z_k will be constant; plugging (5) and (11) into the free-entry condition (9) and dropping the time index one obtains:

$$g\frac{\pi^B}{r + z} = z^{\frac{1-\beta}{\beta}} \lambda^{-\frac{1}{\beta}} \tag{12}$$

Since the left-hand side of (12) is decreasing and the right-hand side is increasing in z, there is a unique steady state. Implicit differentiation shows that the steady-state level of research is a decreasing function of the rate of time preference r and an increasing function both of the productivity of R&D effort λ and the step size between innovations q.

4 Cournot competition

In this section we cover new ground by assuming that firms compete in quantities in the product market. This assumption has two important consequences. First, two or more firms will be active at equilibrium, so that different vintages of the intermediate good will be simultaneously produced even if older vintages are less productive. This means that the market equilibrium will exhibit a new type of inefficiency, productive inefficiency. Second, innovators' rents will not be terminated by the occurrence of the next innovation, although the market share and profits of the current technological leader will decrease, and less efficient firms may be driven out of the market. We now develop the model solution under Cournot competition and our maintained assumption that in each period the next innovation is obtained by an outsider.

To determine equilibrium price, output and market shares in the market for the intermediate good, it is convenient to measure the intermediate good in efficiency units as in equation (3), that takes into account that one unit of the intermediate good of vintage $k-s$ is equivalent to q^{-s} units of the state-of-the-art good. The demand function for the intermediate good is obtained as in the previous section replacing x_k with X_k and therefore is

$$X_k = \alpha^{\frac{1}{1-\alpha}} p_k^{-\frac{1}{1-\alpha}} g^k \,, \tag{13}$$

or Xg^k, where

$$X = \alpha^{\frac{1}{1-\alpha}} p_k^{-\frac{1}{1-\alpha}} \,. \tag{13'}$$

Recall that only the $(k-s)$th innovator, who holds a patent on his vintage of the good, can produce the intermediate good of vintage $k-s$. Under the assumption that all innovations are obtained by outsiders, no innovator will hold multiple patents. Innovator $k-s$'s unit cost of producing one unit of the intermediate good, measured in period k efficiency units, is therefore

q^s. Thus we can proceed as if the intermediate good was homogeneous but firms had different production costs, i.e. 1 for the latest innovator, q for the penultimate innovator, q^2 for the third latest innovator and so on.

Given the demand function (13), it is now easy to calculate the Cournot equilibrium. Let $m_k + 1$ denote the number of active firms in period k. The equilibrium price is

$$p_k = \frac{1 + q + q^2 + ... + q^{m_k}}{m_k + \alpha} \tag{14}$$

The equilibrium number of active firms other than the latest innovator, m_k, is the largest integer such that

$$\frac{1 + q + q^2 + ... + q^{m_k}}{m_k + \alpha} \geq q^{m_k+1} \tag{15}$$

and is therefore constant across periods. Let us denote it by $\bar{m}$. From (14) we obtain

$$p^C = \frac{1 + q + q^2 + ... + q^{\bar{m}}}{\bar{m} + \alpha} \tag{16}$$

Plugging this expression into (13), equilibrium output becomes

$$X_k^C = \alpha^{\frac{1}{1-\alpha}} \left(\frac{1 + q + q^2 + ... + q^{\bar{m}}}{\bar{m} + \alpha} \right)^{-\frac{1}{1-\alpha}} g^k , \tag{17}$$

or $X^C g^k$, where $X^C = \alpha^{\frac{1}{1-\alpha}} \left[\frac{1+q+q^2+...+q^{\bar{m}}}{\bar{m}+\alpha} \right]^{-\frac{1}{1-\alpha}}$. Clearly, the equilibrium price under Cournot competition is greater than under Bertrand competition; consequently, (given k) the equilibrium output is lower.

Let $\pi^C_{s;k}$ and $\sigma_{s;k}$ denote the profit and market share of innovator $k - s$ in period k. We have:

$$\sigma_s = \frac{\left(p^C - q^{s-1} \right)}{(1 - \alpha) p^C} \tag{18}$$

that is, market shares are constant across periods, and , $\pi^C_{s;k} = \pi^C_s g^k$, where

$$\pi^C_s = \sigma_s \left(p^C - q^{s-1} \right) X^C \tag{19}$$

Next consider the equilibrium in the research industry. The zero-profit condition for outsiders (9) continues to hold, but now to determine the value of innovation $k+1$ we must keep in mind that innovator $k+1$ will be active (and get positive profits) for $\bar{m}+1$ periods. The asset condition (10) must therefore be replaced by

$$rE(V_{k+1}) = \pi_0^C g^{k+1} - \lambda_{k+1} n_{k+1}^{\beta} \left[E(V_{k+1}) - E(V_{k+1}^1) \right] \tag{20}$$

where $E(V_{k+1}^1)$ is the value of innovation $k+1$ after one period, i.e. when innovation $k+2$ is obtained. Equation (20) differs from (10) because the capital loss that will be incurred when the next innovation is achieved is the difference between the value of being leader and that of being the second most efficient firm in the market, $E(V_{k+1}^1)$. This is in turn determined by condition

$$rE(V_{k+1}^1) = \pi_1^C g^{k+2} - \lambda_{k+2} n_{k+2}^{\beta} \left[E(V_{k+1}^1) - E(V_{k+1}^2) \right] \tag{21}$$

where $E(V_{k+1}^2)$ is the value of innovation $k+1$ when innovation $k+3$ occurs, and so on. Eventually, after $\bar{m}$ innovations, the $k+1$-th innovator will be driven out of the market. This implies that $E(V_{k+1}^{\bar{m}+1}) = 0$, and hence

$$rE(V_{k+1}^{\bar{m}}) = \pi_{\bar{m}}^C g^{k+\bar{m}+1} - \lambda_{k+\bar{m}+1} n_{k+\bar{m}+1}^{\beta} E(V_{k+1}^{\bar{m}}) \tag{22}$$

These equations can be solved recursively yielding

$$E(V_{k+1}) = \frac{\pi_0^C g^{k+1}}{(r+\lambda_{k+1} n_{k+1})} + \sum_{s=0} \frac{\pi_s^C g^{k+s+1} \prod_{h=0}^{s-1} (\lambda_{k+h+1} n_{k+h+1})}{\prod_{h=0}^{s} (r+\lambda_{k+h+1} n_{k+h+1})} \tag{23}$$

Equation (23) is analogous to (11) in that it says that the value of the $k+1$-th innovation is the present value of all future profits that the innovator will get in the $m+1$ periods for which he will be active in the product market. As usual, the discount factor is augmented to keep into account the probability that new innovations occur.

In a stationary equilibrium, the free-entry equilibrium condition (9) and equation (23) give us:

$$\frac{g}{(r+z)} \left[\pi_0^C + \sum_{s=1} \frac{\pi_s^C g^s z^s}{(r+z)^s} \right] = z^{\frac{1-\beta}{\beta}} \lambda^{-\frac{1}{\beta}} . \tag{24}$$

This equation uniquely determines the equilibrium hazard rate, z. Again, the steady-state level of research is a decreasing function of the rate of time preference r and an increasing function both of the productivity of R&D effort λ and the step size between innovations q.

5 Competition and growth

Having solved the model under Bertrand and Cournot competition, we are now ready to compare the two equilibria. Since the notion of increased competition is traditionally associated with a switch from Cournot to Bertrand competition, such a comparison offers new insights into the relation between competition and growth. We begin with a simple result.

Proposition 1 *If industry profits under Bertrand competition are at least as large as under Cournot competition, i.e. if* $\pi^B \geq \sum_{s=0}^{\overline{m}} \pi^C_s$*, then the Bertrand rate of growth will be higher than the Cournot rate of growth.*

Proof. Note that the following transversality condition must hold:

$$r > (g - 1)\, z\,, \text{ i.e. } \; gz < r + z\,. \tag{25}$$

If this condition is violated, consumers have an incentive to postpone consumption indefinitely. The result then follows immediately from the comparison of (12) and (24) and the transversality condition. ■

The intuition is as follows. Under Bertrand competition, the k-th innovator will get industry profits in period k and zero profits thereafter. By contrast, under Cournot competition an innovator will be active, and reap positive profits, for $\overline{m} + 1$ periods: in the first period he is the technological leader, in the second period he is the most efficient competitor of the new leader, in the third period he is the next best competitor of the new leader and so on. Note that while his relative position in the intermediate good market is modified by the advent of each successive innovation, the profits associated with any of these positions increase across periods by the constant factor g. Hence, in equation (24), the factor gz adjusts current innovator's future profits for both the probabilistic and the growth components related to the next innovations, while $r + z$ is the augmented discount factor of these profits. In a stationary equilibrium the expected length of each period is constant, and so if gz was equal to $r + z$, the incentive to innovate would be the same as if the innovator got aggregate industry profits in the first period and zero profits thereafter (just as he does under Bertrand competition). But the transversality condition implies that $gz < r + z$. This means that the rate of growth under Cournot competition is lower than under Bertrand competition, for any given level of industry profits.

Next we show that industry profits are in fact larger under Bertrand competition if the size of innovations is sufficiently large. Recall that we assume that innovations are non-drastic, i.e. $q < \frac{1}{\alpha}$.

Proposition 2 There exists a left neighborhood of $\frac{1}{\alpha}$ such that if the size of the innovations, q, lies in this interval, industry profits under Bertrand competition are greater than under Cournot competition.

Proof. If q is sufficiently close to $\frac{1}{\alpha}$, the following inequality must hold:

$$\frac{1+q}{1+\alpha} < q^2 . \tag{26}$$

This imply that $\overline{m} = 1$ so that there are two active firms in each period under Cournot competition. Equilibrium profits under Cournot competition are[4]

$$\pi_0^C(q) = \frac{1}{1-\alpha}\alpha^{\frac{1}{1-\alpha}} \left(\frac{q-\alpha}{1+q}\right)^2 \left(\frac{1+q}{1+\alpha}\right)^{-\frac{\alpha}{1-\alpha}} \tag{27}$$

$$\pi_1^C(q) = \frac{1}{1-\alpha}\alpha^{\frac{1}{1-\alpha}} \left(\frac{1-\alpha q}{1+q}\right)^2 \left(\frac{1+q}{1+\alpha}\right)^{-\frac{\alpha}{1-\alpha}} , \tag{28}$$

so that the industry profits are

$$\pi^C(q) = \frac{1}{1-\alpha}\alpha^{\frac{1}{1-\alpha}} \left[\left(\frac{1-\alpha q}{1+q}\right)^2 + \left(\frac{q-\alpha}{1+q}\right)^2\right] \left(\frac{1+q}{1+\alpha}\right)^{-\frac{\alpha}{1-\alpha}} . \tag{29}$$

On the other hand, we recall that Bertrand equilibrium profits are given by

$$\pi^B(q) = \alpha^{\frac{1}{1-\alpha}}(q-1)\, q^{-\frac{1}{1-\alpha}} .$$

[4] At any stage k of the innovative process, both Cournot and Bertrand equilibrium profits are multiplied by the common factor g^K. Obviously this factor is immaterial to the comparison, and hence we ignore it. Also, we introduce the notation "$\pi(q)$" to indicate Cournot and Bertrand equilibrium profits as functions of the size of innovations, q:

We must compare $\pi^B(q)$ to $\pi^C(q)$. First of all, note that $\pi^B(\frac{1}{\alpha}) = \pi^C(\frac{1}{\alpha})$ and both are equal to the monopoly profit associated with the demand function (13') and unit marginal costs. Then, it can be easily shown that $\pi^B(q)$ is monotonically increasing in q, whereas $\pi^C(q)$ is first decreasing and then increasing in q. Let us calculate

$$\frac{\partial \pi^B(q)}{\partial q} = \pi^B(q)\frac{1 - \alpha q}{(1 - \alpha)\, q\, (q - 1)} \tag{30}$$

so that $\frac{\partial \pi^B(q)}{\partial q}|_{q=\frac{1}{\alpha}} = 0$. On the other hand,

$$\frac{\partial \pi^C(q)}{\partial q} = \frac{\pi^C(q)}{(1+q)}\left\{\left[\frac{2(1+\alpha)^2(q-1)}{(q-\alpha)^2 + (1-\alpha q)^2}\right] - \frac{\alpha}{(1-\alpha)}\right\} \tag{31}$$

so that $\frac{\partial \pi^C(q)}{\partial q}|_{q=\frac{1}{\alpha}} > 0$. This means that $\pi^C(q)$ raises more steeply than $\pi^B(q)$ in a left neighborhood of $\frac{1}{\alpha}$. By continuity, it follows that $\pi^B(q) > \pi^C(q)$ in a left neighborhood of $\frac{1}{\alpha}$. ■

Propositions 1 and 2 implies that the equilibrium rate of growth is greater with Bertrand than with Cournot competition if innovations are sufficiently large. The intuition is that with $q = \frac{1}{\alpha}$ both the Bertrand and the Cournot model yield the monopoly solution. Starting from $q = \frac{1}{\alpha}$, consider now the effect of decreasing q. With Bertrand competition, the presence of a less efficient competitor (namely, the holder of the patent on the previous innovation) now constrains the technological leader that must price at $p = q$, but when q is close to the monopoly price $\frac{1}{\alpha}$ the effect of competition on the leader's profit is second order as the profit function is flat at $p = \frac{1}{\alpha}$. With Cournot competition a fall in q will reduce the equilibrium price less than under Bertrand competition, but now the less efficient firm will hold a positive market share that increases as q decreases. Since the less efficient firm's cost is greater than 1, with Cournot competition the effect on industry profits of a fall in q is first order, whence the result follows.

It can be shown that as q falls, eventually $\pi^B(q) < \pi^C(q)$. By Proposition 1, this means that the rate of growth can (but need not) be greater with Cournot competition if the size of innovations is sufficiently small.

Numerical calculations show that the interval in which aggregate profits are greater under Bertrand competition, and thus more competition is associated with faster growth, can be quite large. Figure 1 illustrates.

6 Welfare

We now turn to the effect of competition on social welfare.

Expected social welfare is given by

$$E(u) = \int_0^{\infty} \left(\sum_{k=0}^{\infty} \Pr(k;t)\, c_k \right) dt \tag{32}$$

where $\Pr(k;t) = \frac{e^{-zt} z^k t^k}{k!}$ is the probability that there will be exactly k innovations up to time t, and $c_k = y_k - X_k - n_k$ is consumption in period k.

A switch from Cournot competition to Bertrand competition has two effects on social welfare, a static effect and a dynamic effect. The static effect is unambiguously positive. Indeed, for any given state of the technology, the price of the intermediate good is lower and output is greater with Bertrand competition. Further, under Bertrand competition only the most efficient firm is active in the intermediate good industry (i.e. at each stage of the innovation process, only the highest quality good is produced in equilibrium). The dynamic effect, that operates via the incentive to innovate and the rate of growth, is more complex. As we have seen, more competition may be growth-enhancing or growth-reducing. In addition, as is well known, the equilibrium rate of growth may exceed the socially optimal rate, which means that faster growth is not necessarily socially beneficial. It follows that the welfare effect of more competition is generally ambiguous.

However, if innovations are sufficiently large so that Proposition 2 applies, and if the equilibrium R&D effort is suboptimal, as empirical estimates seem to indicate, more competition will have a positive effect on social welfare.

We cannot rule out, however, the case in which the equilibrium rate of growth is too high and the dynamic effect outweigh the static one, so that less competition is socially desirable. This possibility was first pointed out by Delbono and Denicolò (1990) in a partial equilibrium framework, and can be re-obtained in our general equilibrium model for non-degenerate values of the parameters (numerical examples are available from the authors upon request).

7 Concluding remarks

In this paper, we have re-considered the relationship between competition and growth in a standard neo-Schumpeterian model with improvements in the quality of products. We have modeled the notion of lower competition by a switch from Bertrand to Cournot competition, focusing on the case of non-drastic innovations.

Our main …nding is that when the size of innovations is su¢ ciently large, the equilibrium rate of growth is unambiguously greater with Bertrand than with Cournot competition. This result follows from two e¤ects that our analysis has highlighted. First, for any given level of industry pro…ts, the incentive to innovate is larger under Bertrand competition because with Cournot competition part of the innovator's rents are delayed. Second, when innovations are close to being drastic, the productive e¢ ciency e¤ect implies that industry pro…ts are greater with Bertrand competition.

However, for smaller innovations, Cournot competition may (but need not) create greater incentives to innovate (hence greater rates of growth). Even if innovations are large the welfare comparison of the Bertrand and Cournot equilibria is generally ambiguous.

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Figure 1

- Comparison of Bertrand and Cournot equilibrium profits as functions of the size of innovations -

Fig.1.a ($\alpha = 0.1$)

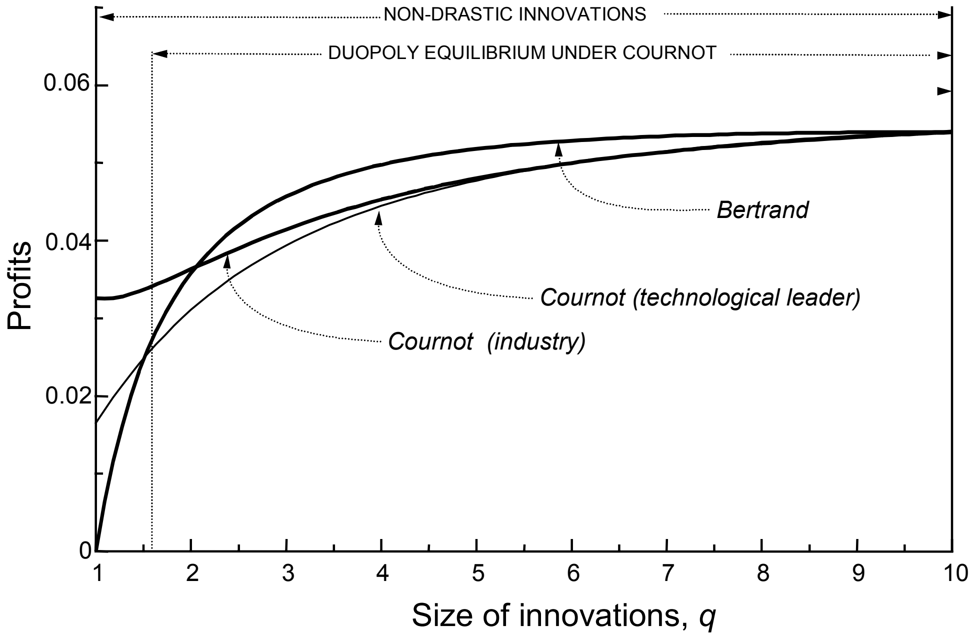

Fig.1.b ($\alpha = 8/9$)