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Economic Integration, Intensity of Competition and R&D Incentives*+

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Abstract

A two-country differentiated duopoly model is set out in which economic integration increases firms' incentives to invest in R&D, purely through the effect of increased intensity of competition between firms. The model is extended to incorporate knowledge spillovers, which, if related to the degree of integration, give rise to an inverted u-shaped relationship between R&D incentives and integration. The model is also extended to the n-firm general equilibrium case in which integration stimulates economic growth through intensity of competition. As such, the model suggests a positive growth effect of economic integration that does not rely on the usual scale effects.

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1: Introduction

If there are dynamic efficiency gains to be made as a result of economic integration then it is possible that integrating a set of economies may lead to a higher long run rate of growth. This possibility has attracted some attention in recent years as regional and global integration has progressed, A variety of ways in which the R&D and subsequent innovation decisions of profit maximising entrepreneurs might be affected by integration have been suggested. The most generally used arguments are that integrating a number of economies enlarges the market and knowledge base available to firms and may therefore enable them to exploit scale economies in R&D.

The *technology-push* hypothesis discussed by Phillips (1966) argues that there is a relationship between the level of underlying scientific knowledge in an economy and the rate of technological progress. Rivera-Batiz and Romer (1991) argue that if the rate of innovation is positively related to the current stock of knowledge capital in an economy, economic integration will allow access to an international stock of knowledge and therefore increase the rate of technological progress. Rivera-Batiz and Romer (1991) also discuss the importance of what Schmookler (1966) referred to as the *demand-pull* hypothesis, where integration presents a bigger market and therefore a greater reward to a successful innovator. This market enlargement effect will have an unambiguously positive effect on incentives to innovate, other things being equal. The problem with these predictions is that empirical evidence for such scale effects is, at best, mixed.

At the same time as these scale effects, integration will change the nature of the competition facing firms. Markets will be characterised by increased intensity of competition resulting in extra pressure on home market shares and added opportunities to steal shares in foreign markets. It is likely that such changes in the intensity of competition will have an effect on R&D incentives. These 'increased competition' effects of integration have not, so far, received as much attention in the literature as the demand-pull and technology-push scale effects. However, a considerable wealth of knowledge on these matters can be found in the IO literature. Drawing on this literature, this paper takes a closer look at the competition effects of integration and their implications for R&D and long run growth.

The remainder of this paper is set out as follows. The following Section discusses the IO literature on competition and innovation and some of the particular characteristics of these models that may have critical implications when they are extended to consider integration. Section 3 presents a simple two-firm two-country model where integration is modelled as an increase in the substitutability between differentiated goods. Two interesting special cases of this model are also considered: Firstly, when firms are allowed to co-operate in research and secondly when the extent of appropriability of R&D is related to the degree of integration. Section 4 extends the model to allow for asymmetric initial costs of production. Section 5 further extends the basic symmetric model to an n-sector general equilibrium model in which national growth rates are shown to be positively related to the intensity of competition and therefore the degree of integration. Section 6 summarises and concludes.

2: Intensity of Competition, Integration and R&D

How might increased intensity of competition affect R&D? More intense competition will make a firm's share of its market more vulnerable to successful innovation from its competitors. This will give added incentives to keep up with R&D. Equally, successful innovation will allow the firm to more easily expand its share of a given market at the expense of its competitors by stealing their shares (Sutton, 1996). In other words, there is strategic complementarity in R&D between firms (Miyagiwa & Ohno, 1997). These strategic considerations add to R&D incentives when competition is intensified.

However, as ever, the story is not that simple. The relationship between concentration and R&D incentives may be very different for different types of innovation and different types of competitive behaviour. For example, the relationships between R&D aimed at reducing production costs and market concentration, and between R&D aimed at introducing new products and concentration may be of opposite sign (Cohen & Levin, 1989). Sutton (1996) finds a similar discrepancy between quality improving R&D and new product R&D.

Many authors have discussed the different implications for R&D incentives of modelling competition by quantity or by price (Cournot or Bertrand), mainly for process innovation. Brander and Spencer (1983), for example, argue that Cournot competition favours innovation in that one firm's cost reduction will lower the output of its competitors, whereas under Bertrand competition, a cost reduction will lower its competitors' price. In general, no real consensus has emerged as to the relationship between concentration and R&D under either Cournot or Bertrand competition. For example, for a homogenous good and process innovation, Dasgupta and Stiglitz (1980) find a negative relationship between R&D and competition. Qui (1994) finds a negative relationship under Bertrand and a U-shaped relationship under Cournot.

Bester and Petrakis (1993) find a positive relationship between the degree of product substitutability and R&D incentives for both Cournot and Bertrand competition, and that incentives to innovate are higher (lower) under Bertrand than Cournot for a high (low) degree of substitutability.[1]

This lack of consensus highlights the sensitivity of results to the particular assumptions on which these models are built. I discuss three such assumptions below, which are of particular interest in the current paper. Firstly, the specification of linear demand functions is shown to have critical implications. Secondly, the degree of appropriability of the benefits of R&D can be important. Thirdly, the degree to which firms can co-operate in research has implications for the competition/R&D relationship.

Given the overall ambiguity of the competition/R&D relationship in the theoretical literature, a critical role for empirical evidence is implied. However, the empirical literature is also lacking consensus and evidence is mixed. Positive relationships between competition and innovation are found by, for example, Horowitz (1962) and Mansfield (1968). Williamson (1965) and Bozeman and Link (1983) find negative relationships. Scherer (1967) finds evidence of a non-linear inverted U-Shaped relationship, with an optimum degree of competition. Sutton (1996) shows how apparent relationships are weakened when industry-specific effects, such as technological opportunity, are included. Problems with data, such as distinguishing between process and product innovations and the lack of reliable industry level elasticity estimates have prevented a definitive empirical examination of these matters.

[1] The degree of substitutability is the measure of competition intensity I adopt here.

There is also the added complication of reverse causality between R&D and concentration. Cohen and Levin (1989) discuss these problems in a detailed review of the empirical market concentration and R&D literature, pre 1989.

A key assumption shared by the models of Brander and Spencer (1983), Bester and Petrakis (1993), Qui (1994) and Sutton (1996) is the specification of linear demand functions.[2] With such a linear demand specification, increasing the substitutability between goods, or increasing the intensity of competition, has the effect of shrinking the size of the market available to each firm. This effect is outlined and contrasted with the effect of increasing substitutability in the non-linear demand specification adopted in the current paper. It is this shrinking market effect that is behind Qui's predicted U-Shaped relationship, with R&D incentives being driven by a similar shaped marginal profits function. More specifically, R&D incentives are responding to the interaction between the negative shrinking market effect and the positive strategic market-share effects discussed above, which eventually dominate. In what follows, I adopt a non-linear demand specification that does not have this shrinking market effect. This is more appropriate to a study of integrating markets, whereas the linear demand specification may be more appropriate to studies of entry into given markets. This is my first formal point of departure from the IO literature.

The usual linear demand specification (taken from Qui (1994)) is as follows:

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[2] In fact, Sutton presents both a relatively simple linear model and a less simple, but more general, bounds-approach model. He advises us to take both theoretical results from such simple linear models and the empirical results from related simple regression models with caution.

$$p_i = \alpha_i - q_i - \gamma q_j, \tag{1}$$

where γ ($0<\gamma<1$) is the degree of substitution between the two goods and i and j denote competing firms. Inverting and summing over i gives us total market demand:

$$q_i + q_j = \{(\alpha_i + \alpha_j) - (p_i + p_j)\}/(1 + \gamma). \tag{2}$$

This is clearly decreasing with γ.

In contrast, the non-linear demand specification adopted in the model of the following Section displays market-size stability when the degree of substitutability is altered, as shown by (3). For simplicity, I assume symmetric prices, $p_i = p_j = p$.

$$q_i + q_j = 2mp^{-\gamma}/2p^{1-\gamma} = mp^{-1}, \tag{3}$$

Clearly, in this case, market size is invariant with γ.

Another common assumption in the IO literature on concentration and innovation discussed above is the full appropriability of the benefits of R&D, or in other words, that there are no knowledge spillovers. The presence of such spillovers has been shown to have important implications for R&D incentives in a related literature on R&D co-operation (see, for example, D'Aspremont & Jacquemin 1989; Kamien et al, 1992). These papers argue that the incentives to invest in R&D will be lower if some of the benefits of that R&D spill over to firms in direct competition, because spillovers will lessen the relative advantage to be gained over these competitors. For firms not in direct competition, this is not such an important consideration. If we accept this argument, then integration should increase this spillover disincentive for R&D. This is likely to have important implications for the overall integration/R&D relationship through intensity of competition effects, and is another point of departure from the papers discussed above.

The assumption of incomplete appropriability is given further importance in this context if we assume the level of spillovers is related in some way to the degree of integration between firms or countries. That knowledge spillovers across national boundaries might be positively related to the level of interaction between countries has been suggested by, among others, Grossman and Helpman (1991). There is also strong evidence that flows of goods within countries are highly correlated with spillovers between firms and industries. If this is the case, then integration, by strengthening spillovers, may have a further disincentive effect on R&D. This possibility is considered in Section 3.3, and is shown to have some very interesting implications. In particular, the interaction of the positive strategic and negative spillover effects can lead to an inverted U-Shaped relationship between R&D incentives and integration, suggesting the possibility of an optimum level of integration.

R&D co-operation and integration is an area of research that has been largely overlooked so far in the literature, although claims have been made that integration might stimulate co-operation and therefore dynamic performance (Cecchini, 1988). To recap, co-operation in research, or research joint ventures (RJVs) may have benefits and costs. On the one hand, knowledge may diffuse more quickly between venturers increasing the social rate of return to R&D. Also, because firms explicitly co-operate, the disincentive effects of spillovers may be reduced. Further, high fixed costs in R&D can be shared and economies of scale realised. On the other hand, co-operative research agreements may be anti-competitive in both the research and production markets, which could lead to both dynamic and static inefficiency. According to Ordover and Willig (1985), generally the benefits of co-operation can be expected to outweigh the costs. However, as the degree of product market rivalry increases, a co-operative research agreement is less likely to lead to increased research (Katz, 1985). This is the key point here. By fostering anti-competitive behaviour in RJVs, integration may lead to reduced R&D expenditure and slower technological progress. This is considered in Section 3.2.

One of the most important fault lines running through the competition/R&D literature is the assumption of symmetry or the nature of the asymmetry assumed. Bester and Petrakis (1993) find a firm that has gained a cost advantage in the past is more inclined than its competitors to invest in further cost reductions.[3] In a dynamic setting, this would suggest a dominant firm outcome, such as found by Grossman & Shapiro (1987) and Harris & Vickers (1987), for example. In these models, the follower becomes increasingly disillusioned as the technology gap widens. However, the predictions of these models depend on assumptions made about the technological opportunities facing firms. In many cases, it is assumed that the best followers can do is catch up (see Aghion and Howitt, 1998, for an example). Alternative assumptions can lead to the opposite implications for follower incentives. In Section 4, I present a model where the low-technology firm has the greater incentive to invest in R&D,

[3] This has unfortunate implications for the stability of their symmetric equilibrium.

resulting in a stable symmetric equilibrium. A detailed review of such symmetry considerations is provided by Beath et al (1994).

In the following Section I set up a simple two-firm, two-country model in which integration is modelled by an increase in the substitutability in preferences between the two goods. Although commonly used in the IO literature to model increased competition, this is a novel approach to modelling economic integration. It is not without precedent, however. Danthine and Hunt (1994) adopt the technique in their study of integrating labour markets. What this approach allows is the isolation of the intensity of competition effect from other integration effects, such as demand-pull. By modelling integration in this way the market enlargement effect of integration disappears. A market may become twice as big, but a firm’s share of this market is divided by half because the number of equal competitors doubles. This is perhaps the most crucial assumption of the model presented in the following Section. By concentrating solely on the strategic intensity-of-competition effects of integration on R&D, this paper formalises an alternative mechanism through which integration can affect long run growth to the standard scale effects discussed above.

Before presenting the model, it is useful to consider the legitimacy of modelling integration in this non-standard way. The simplest justification is to think of integration as being a standardization process. For example, European integration may involve the standardization of electrical products to common European specifications. The benefit of this interpretation is that it requires no leap of imagination to swallow, although there is a cost in terms of the narrowness of the integration concept. However, if we are prepared to take a small intuitive step, this way of modelling integration can be thought of in much broader terms. Danthine and Hunt (1994) warn that we should not take it literally that integration manifests itself as a change in consumer preferences. However, from the producer's point of view, it is *as if* integration has caused preferences to shift. Consumers pay more attention to goods sold by foreign producers. Market shares become more sensitive to price differentials as competition is intensified. A simple example is presented below in order to clarify this concept.

Imagine two supermarkets, far enough apart so that consumers living near one cannot walk to the other costlessly and vice versa. This would manifest itself as if the food products offered by the two supermarkets were not close substitutes in preferences, with the supermarkets having monopoly power over the consumers living at their end of town. Overall market share would be insensitive to the prices set in the other supermarket at the other end of town. Now consider a reduction in the barriers to trade, such as the introduction of a free bus service between the supermarkets. Consumers could now shop at either supermarket costlessly, which would manifest itself as if the products offered by the supermarkets were closer substitutes. The market share of each supermarket would now be much more sensitive to the price setting of the other supermarket. Intuitively, we can consider integration in this way.[4]

[4] A companion paper reworks the model of Section 3, for the symmetric competitive case, with integration modelled in the more standard way as falling tariffs. The fundamental results of the model are unchanged in this alternative (see McVicar, 1999).

3: A Two-Country Duopoly Model of Integration with Process Innovation

At the expense of a modicum of generality, the following model allows the intensity of competition effects of integration on R&D to be formalised in a very simple way. The stylized nature of the model does not detract from the potential of its conclusions, however. It is left to further research to relax some of the more extreme assumptions in order to generalise the model's predictions. In the light of this, the model should be seen as a first step in formalising the intensity-of-competition effects of integration on growth through R&D, rather than an end product. This step is made all the more important given the continuing lack of convincing evidence for scale effects, such as those suggested by Rivera-Batiz and Romer (1991).

Consider an industry consisting of two firms, each producing a single differentiated good. Assume for now that entry into the market is impossible, due to, say, high fixed costs that have been paid in the past by the incumbents. This assumption simplifies the analysis, allowing the isolation of integration effects through intensity of competition.

Imagine that the first firm is located in the first of the two countries and that the other is located in the second country. As in Rivera-Batiz and Romer (1991), consider only similar countries, so avoiding any question of comparative advantage.[5] With this approach, the existence of these countries is not explicitly modelled, and there is no

[5] Section 4 relaxes this assumption to allow technological superiority in one of the countries. All else is symmetric.

explicit modelling of international trade.[6] However, thinking of the market for the two goods as being made up of these two countries allows a significantly different interpretation of an otherwise fairly standard differentiated duopoly model. Integration is modelled as an increase in the elasticity of substitution in consumer preferences between the two goods, which is assumed to be exogenous.

Identical consumers across both countries have Cobb-Douglas preferences over a composite of the R&D goods and a non-R&D competitive good. They therefore spend a fixed proportion of their income, m, on the two goods, i and j, which they do according to the constant elasticity of substitution (CES) utility function given by equation (4).

$$U(q_k) = \{q_{ik}^{(\theta-1)/\theta} + q_{jk}^{(\theta-1)/\theta}\}^{\theta/(\theta-1)}, \text{ for all } \theta>1, \text{ for consumer k.} \quad (4)$$

The parameter θ is the elasticity of substitution in preferences between the two goods. Consumers divide their lump of income, m, between the two goods, giving us a representative consumer's demand for each good, as given by equation (5).

$$q_{ik}(p,m) = mp_i^{-\theta}/(p_i^{1-\theta} + p_j^{1-\theta}), \text{ and similarly for good 2.} \quad (5)$$

The demand curves (6) facing each firm can be found by summing over all consumers, where 'a' denotes the aggregate of the m's. The resulting non-linear specification of

[6] All that is required is some way of differentiating between consumers located close to the producer of good 1 and consumers located close to the producer of good 2, whether geographically, or in some other sense.

the demand curve does not share the shrinking market effect of Qui (1994) and Bester and Petrakis (1993) and is therefore more suitable for a study of economic integration. Increasing the elasticity of substitution makes market share more sensitive to price but does not reduce market size.

$$q_i = ap_i^{-\theta}/(p_i^{1-\theta} + p_j^{1-\theta}). \tag{6}$$

Costs of production are linear and given by:

$$C_i(q_i) = c_i q_i. \tag{7}$$

Firms may invest in deterministic R&D which results in process innovation, reducing unit costs by $f(X_i)$, where X_i denotes the effective level of research, given by (8), with x_i being firm i's investment in research and β being the spillover parameter between firms, $0 \leq \beta \leq 1$, assumed to be exogenous.

(3.8): $X_i = x_i + \beta x_j$,

This set up for R&D is an extension of that of D'Aspremont and Jacquemin (1988) and Kamien et al (1992). Following these earlier papers, I assume $f(X_i)$ to be concave, and more precisely to be defined as:

$$f(X_i) = c_i X_i^{1/2}. \tag{9}$$

Therefore R&D displays diminishing returns. D'Aspremont and Jacquemin (1988) cite Dasgupta (1986) as evidence in support of such a concave R&D function. The extent to which costs can be reduced through R&D is also related to the level of initial costs. In other words, it gets more difficult, in absolute terms, to reduce unit costs through time. This assumption is necessary in order to ensure a constant growth rate in the extension to the model presented in Section 5.[7]

Firms play a two-stage game. First they determine R&D expenditure, x, which determines unit costs for stage 2 in which there is Cournot competition.[8] Three alternative scenarios are considered. First, firms have identical initial production costs and compete in both stages of the game. This case is worked through in Section 3.1 below. An interesting extension of this case is presented in Section 3.3, where spillovers and integration are related. Secondly, firms with identical unit costs compete in the product market but can co-operate in the R&D stage. This is shown in Section 3.2. Thirdly, I consider the case where one firm has an initial cost advantage, due, for example, to a higher level of innovation historically. The first two scenarios can be solved analytically. The third is solved numerically in Section 3.4. In all cases, the model is treated simply as a one-shot game.

3.1: R&D Competition with Identical Unit Costs

[7] It is not necessary to obtain the partial equilibrium results, however. An earlier version of the model assumes $f(X_i) = X_i^{1/2}$ and the same pattern of results is obtained (see McVicar, 1998).

[8] I am implicitly assuming there is no difficulty in obtaining funding to carry out R&D from retained past profits.

Equation (9) assumes both firms have the same R&D opportunities, being in the same industry, and that they face the same R&D function, which follows from the assumption of similar countries. These symmetry assumptions lead us naturally to a symmetric equilibrium.

Consider the stage 2 output decision In the second stage, firm i finds its profit maximizing level of output, for a given level of R&D expenditure in stage 1. Total costs are given by (10) and revenue, after first inverting the demand curve, by (11). Hence profits are given by (11) – (10). The subscripts are not dropped from unit costs at this stage for consistency with the asymmetric case outlined in Section 4.

$$TC_i = (c_i - f(X_i))q_i + x_i. \tag{10}$$

$$TR_i = a / \{(q_j/q_i)^{(\theta-1)/\theta} + 1\}. \tag{11}$$

The marginal condition for firm i is given by (12), where $\phi = (\theta\text{-}1)/\theta$.

$$c_i - f(X_i) = [a\phi(q_j/q_i)^{\phi}] / [q_i\{(q_j/q_i)^{\phi} + 1\}^2]. \tag{12}$$

The Cournot model displays the standard downward sloping reaction curves, so the two goods are strategic substitutes. Manipulation of equation (12) and the mirror equation for firm j, gives us:

$$q_j = q_i\,[c_i - f(X_i)] / [c_j - f(X_j)]. \tag{13}$$

So, relative outputs just depend on initial costs and R&D expenditures. If a firm can adopt a lower cost technology than its competitor, it can increase its market share at the expense of the higher cost firm. Matters are further simplified here because initial unit costs are assumed to be equal, so that output shares just depend on differences in R&D expenditures. This is where the R&D incentive comes from in the model. The incentive is purely strategic. No other R&D incentive exists.[9]

Substituting (13) into (12) gives us the firm's profit maximizing level of output, as shown in (14). Let F(X) denote $[c_i - f(X_i)] / [c_j - f(X_j)]$.

$$q_i = [a\phi F(X)^{\phi}] / [(c_i - f(X_i)\{F(X)^{\phi} + 1\}^2]. \tag{14}$$

Substituting (14) into the expression for profits (11)–(10), gives profits in terms of R&D expenditure:

$$\Pi_i = [a + (a/\theta)F(X)^{\phi}] / [\{F(X)^{\phi} + 1\}^2] - x_i. \tag{15}$$

In Stage 1, the firm sets the profit maximizing level of R&D expenditure, x_i. Notice that $\partial X_i/\partial x_i = 1$ and that $\partial X_j/\partial x_i = \beta$. Given that the model has been set up with symmetry maintained throughout, there is nothing to make one firm's R&D decision any different to the other's, so $x_i = x_j$. The first order conditions give us the following expression for optimal effective R&D:

[9] Because of the cost of R&D, in symmetric equilibrium, profits are decreasing in R&D expenditure. If there was no competition and no threat of entry, the firm wouldn't bother at all.

$$X_i^{1/2} = 1/2 \pm [\sqrt{\ }\{1 - a(1-\beta)(\theta-1)/2\theta\}]/2. \tag{16}$$

Second order conditions rule out the larger of these two solutions. So, the smaller of the two solutions denotes profit-maximizing effective R&D level.

In order to ensure a non-negative expression in the square root, the parameters have to obey the following condition:

$$1 \geq a(1-\beta)(\theta-1)/2\theta. \tag{17}$$

Rearranging gives us a condition linking the demand parameter, a, with the elasticity of substitution, θ, as shown in (18):

$$\theta \leq a/(a-2). \tag{18}$$

The condition is binding when $\theta=a/(a-2)$. In other words, for the model to be valid, $a\geq2$. When a is close to 2, θ can be large. When a is large, θ must approach 1.

Figure 1 shows firm i's profit function for a given level of firm j R&D expenditure. The local maximum and minimum are clear. Note that profits tend to infinity as R&D expenditure tends towards 1. However, this extreme scenario can be ruled out by assuming there is some lower bound on post-R&D costs at all times: $x_i<0.25$, for example.

From (16) it can be seen that:

$$\partial(X_i^{1/2})/\partial\theta = a(1-\beta)/\{8\theta^2\sqrt{\;}\,[1 - a(1-\beta)(\theta-1)/2\theta]\}, \tag{19}$$

which is positive for all $\beta<1$. So, integration, as measured by an increase in the substitutability parameter, θ, leads monotonically to a higher level of effective R&D for any given level of spillovers. Therefore firms' expenditure in R&D is increasing with integration.

R&D increases with integration at a decreasing rate the more integrated the industry becomes. There is no shrinking market effect, so integration has no negative effect at low levels of integration, such as that found by Qui (1994). As expected, a firm closely integrated with its competitor loses a big slice of its market share if its price is undercut. Equally, it can steal a big slice of its competitor's market share if it can undercut its price. These effects are much more muted when substitutability is low. Although R&D is expensive, and although cost reduction is of no benefit to the firm when matched by its competitor, these strategic incentives to carry out R&D result in a situation where both firms invest more and more the more integrated the industry becomes.[10]

What of the effect of spillovers on R&D? From (16) it can be seen that:

$$\partial(X_i^{1/2})/\partial\beta = -a(\theta-1)/\{8\theta^2\sqrt{\;}\,[1 - a(1-\beta)(\theta-1)/2]\}. \tag{20}$$

Given $\theta>1$, the expression in (20) is negative. In other words, effective R&D and firm's own R&D are decreasing with spillovers. This is a common result for this kind of model (see, for example, D'Aspremont & Jacquemin, 1988). For higher spillovers, investment in R&D lowers the competitor's costs and this increases the competitive pressure on the firm. Also for high spillovers the firm may be tempted to free ride on its rival's R&D expenditure. Both these factors act to lower R&D expenditure. These factors outweigh the positive spillover effect on effective R&D from (8) at all parameter values. In the extreme, with perfect spillovers, there is no R&D carried out at all, since no strategic advantage can be gained.

The negative spillover/R&D relationship is stronger the higher the value of θ. In other words, the more intense is the competition between the firms, the stronger the disincentive effect of spillovers on R&D expenditure. As discussed in Section 2, it is more of a disincentive to lower a direct competitor's costs than a distant competitor's costs.

3.2: R&D Co-operation with Identical Unit Costs

Consider the co-operative research scenario, where firms set R&D expenditure to maximise total industry profits in the first stage, but still compete in the product market in the second stage. This corresponds to D'Aspremont and Jacquemin's second case (D'Aspremont & Jacquemin, 1988) and case C of Kamien et al (1992). This is probably the most realistic scenario of co-operative research since antitrust legislation does not generally encourage product market co-operation but, certainly in Europe,

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[10] The Single European Market (SEM), if modelled in this way, should lead to higher technology levels for European firms and therefore better global competitiveness.

does allow for co-operative R&D in many cases (see Jacquemin, 1988, for an informative discussion of EC Antitrust Law).

Profit maximizing output is given by (14), since firms still compete in the second stage. In (15), firms now maximise $\Pi_{total} = \Pi_1 + \Pi_2$, with respect to research expenditure, x_i. Solving this gives us the corner solution of $\partial\Pi_{total}/\partial x_i = -1$. In contrast to the competitive scenario, there is no longer any strategic incentive to invest in R&D so firms do not conduct any R&D. Firms prefer to co-operate and hold back innovation, since they save themselves wasted R&D costs.[11] For a given level of spillovers, integration increases the profit-gap between the co-operative R&D and competitive R&D scenarios, and therefore increases the incentives to co-operate in R&D. Katz (1985) makes a similar prediction for firms producing a homogenous good under Bertrand competition.

3.3: Integration and Spillovers

Section 2 introduced the possibility of a positive relationship between integration and spillovers. For example, Grossman and Helpman (1991) argue that increased trade between countries will involve increased interaction between agents in different countries and therefore more opportunity for knowledge to pass from agent to agent. Equally, increased trade might lead to more opportunities to reverse engineer technical products. Empirical evidence for such a relationship is strong (see Coe and Helpman, 1995, for example).

[11] There will, however, be an incentive for firms to cheat on the agreement and lower unit costs unilaterally in order to capture a bigger market share. This may make such agreements unstable in the absence of credible punishment strategies.

In the current model, this spillovers/integration relationship can be captured by a simple function, such as (21), where $0 \leq g(\theta) \leq 1$.

$$\beta = g(\theta), \tag{21}$$

with $g'(\theta)>0$, $g''(\theta)<0$ and $g(\theta) \rightarrow 0$ as $\theta \rightarrow 1$.

In other words, a reduction in product differentiation makes it easier for a firm to apply any process innovation by its competitor to its own production process.

Substituting (21) into (16) and differentiating with respect to θ gives us the following expression for the effect on R&D of integration:

$$\partial(X_i^{1/2})/\partial\theta = \{a/8\sqrt{}\ [1 - a(1-g(\theta))(\theta-1)/2\theta]\}.\{(1-g(\theta))/\theta^2 - g'(\theta)(\theta-1)/\theta\}. \tag{22}$$

The first term is positive, as is the first term in the right-hand bracket. The second term in the right-hand bracket is negative which gives us an ambiguous sign for the whole expression. Sketching the relationship shows an inverted U-shaped relationship between integration and effective R&D. With small θ (ie: a high degree of product differentiation), integration leads to a higher level of R&D expenditure. With large θ (ie: a low degree of product differentiation), further integration leads to a lower level of R&D expenditure.

There is therefore an optimal level of integration at which the negative spillover effect and positive competition effects are balanced.[12] This is given by the stationary point of the expression in (22), as shown in (23).

$$\theta^* g'(\theta^*)(1-\theta^*) - g(\theta^*) + 1 = 0. \tag{23}$$

Imposing a simple form on function g that meets the conditions outlined in (21) can give us an illustrative optimum integration level. Take the example of $g(\theta) = 1-1/\theta$. In this case (23) solves for an optimum integration level of $\theta^*=2$. Of course, this is all somewhat stylized. Nonetheless, the suggestion that the interaction of a negative spillover effect on R&D incentives and a positive strategic effect on incentives might give rise to such a non-linear integration/R&D relationship purely through intensity of competition effects is potentially very interesting. If the prediction is robust to generalization of the model in further research, then there may be significant implications for trade policy.

4: R&D with Asymmetric Initial Unit Costs

The results so far have assumed all is symmetric in the model. This means that firms cannot start with a cost advantage, or build such an advantage by their R&D efforts. Also, all the potential benefit in terms of profits from R&D is lost when any cost reduction is matched exactly by the competition. Now consider relaxing the symmetry assumption to allow one firm to have an initial cost advantage, due to, say, historical innovation in cost-reducing processes. Are the relationships between integration, spillovers and R&D robust to this change? I consider only R&D competition in this

[12] Optimal in a growth maximizing sense.

case, leaving aside any question of co-operation. The model is also only considered explicitly as a one-shot game.

The model is exactly the same as that set out in Section 3 except that initial unit costs are not the same for each firm. This means a crucial simplifying assumption is lost at the profit maximizing stage, and the system of non-linear equations, given by maximising (15), can no longer be solved analytically. However, solving the model numerically is relatively straightforward.[13]

Results are presented below, in Tables 1 and 2, for the case where firm 1 has initial unit costs equal to 1.005 and firm 2 has initial unit costs equal to 0.995. In other words, firm 2 has a slight initial cost advantage. The other parameters are set as $a=2$, $\beta=0$, 0.1 and 0.5 and $\theta=2$, 5 and 10. These are chosen as plausible values for zero, low and high spillovers and low, medium and high substitutability. Three points in each range is sufficient to see the pattern of solutions emerge. As long as the parameter values chosen fall within the range determined by the condition $\theta \leq a/(a-2)$, the pattern of the numerical results is consistent with alternative sets of parameter values outside these ranges.

In the asymmetric case, the high cost firm engages in significantly more R&D than the low cost firm, for all permitted parameter values. In other words, the initial cost gap gets endogenously smaller through profit maximising R&D. In fact, the higher R&D expenditure of the high cost firm is always sufficient to equalise post-innovation unit costs, as shown in Table 2. The symmetric equilibrium presented in Section 3.1 is

[13] In this case, Excel is used to obtain approximate numerical solutions.

therefore stable, so that a shock to one of the firm's cost levels is absorbed by the model and the symmetric equilibrium reverted to in a single period. This result is driven by the fact that R&D expenditure is more effective in reducing costs for the high cost firm (from Equation (9)) until technology levels are exactly equalised.[14] Since the benefits to R&D are largely competed away, the low cost firm prefers to save on R&D costs when it can.

Bester and Petrakis (1993) find the opposite result for firms with asymmetric costs, ie: that the low cost firm invests more in R&D than the high cost firm, making the cost gap endogenously wider. This is likely to be the result of the fact that the marginal returns to investment in R&D in the Bester and Petrakis model are increasing over time, as cost reduction is absolute rather than proportional to initial unit costs as in the current model. In other words, the marginal return to R&D is higher for the low cost firm. An alternative version of the current model, with a different specification for Equation (9), where cost reduction does not depend on the level of unit costs, but where all else is unchanged, leads to the same prediction as the Bester and Petrakis model (see McVicar, 1998).[15] Despite obtaining the opposite prediction concerning the evolution of the technology gap using the two alternative specifications for (9), the effects of increasing integration and increasing spillovers are the same in both cases. The current specification for Equation (9) is preferred to the alternative for the stability property of the symmetric equilibrium and to give a constant growth rate in the extension to the model outlined in the following section.

[14] The single-period reversion to symmetric equilibrium is a reflection of the one-shot nature of the model and the small size of the initial cost difference. Making the game dynamic, with a larger cost difference and a limited step-size for cost reduction in each period would slow the process down.

How does R&D expenditure relate to the degree of integration and the level of spillovers? Firstly, R&D expenditure is everywhere decreasing with spillovers, as in the symmetric case. This is unsurprising, since the intuition applies equally to both scenarios. More interestingly, the ratio of high cost to low cost firm R&D expenditure is higher when spillovers are larger, in all cases. In other words, the higher the level of spillovers, the more benefit of the low cost firm's R&D expenditure acts to narrow the technology gap, so the less inclined to invest in R&D it is. The relationship between integration and R&D expenditure is similar in the asymmetric case to that in the symmetric case. In other words, R&D increases at a decreasing rate with integration for both firms. The negative spillover incentives and positive intensity of competition incentives are therefore robust to alternative specifications for initial technology levels.

5: A Symmetric N-Sector Extension

A simple extension to the model of Section 3.1 allows the economy-wide growth rate at a given point in time to be calculated. This is intended to be illustrative of the potential of the model, rather than being a serious contender for a model of endogenous growth and integration in its own right. This is left for further research. The predictions of the partial equilibrium model carry over to the simple general equilibrium model. This has significant implications for the growth/integration literature. Foremost of these is that it is possible for integration to increase the growth rate in a simple R&D-based endogenous growth model, without relying on scale

[15] Cost reduction is defined as $f(X_i) = X_i^{1/2}$ in this alternative specification.

effects, but purely through the effects of the intensity of competition on R&D incentives.

Assume there are a fixed number, N, of sectors, all differentiated duopolies, with one firm in each sector in each country as before. The goods are differentiated both between and within sectors. Cobb-Douglas preferences across sectors ensure a constant proportion of consumer's income is spent on the goods from each sector. Two assumptions allow us to focus on a single representative time period and to apply directly the results of Section 3.1. Firstly, discounted utility and profit functions are additively separable for each period. Secondly, the countries, sectors and firms are all symmetric and all are integrated to the same degree at any one time. Relaxation of this additional symmetry assumption is left for further research. By making this assumption, a common θ is imposed.

Each individual sector is set up as before. A labour endowment, L, is introduced for each country, being the only factor used in production. Innovation can now be thought of as labour saving. Assuming equal sized sectors, with market clearing wages, each firm uses L/N units of labour. The unit cost of production can now be thought of as the amount of labour needed to produce a single unit of output multiplied by the wage, giving total costs as in (24).

$$TC_i = q_i(c_i\text{-}f(X_i))w_i - x_i, \tag{24}$$

where notation carries through from Section 3 and w_i is the wage paid to workers in firm i. .

Total revenue for firm i is given, as before, by equation (11), where firms i and j are two firms in a given sector. Profit maximizing output in Stage 2, for given R&D, is therefore given by the marginal condition (25).

$$q_i = [a\phi F(X_i)^{\phi}] / [w_i(c_i - f(X_i))\{F(X_i)^{\phi}+1\}^2]. \tag{25}$$

Note that $\phi=(\theta-1)/\theta$, as before. The only difference in notation is that $F(X_i)$ now includes a term for relative wages, ie: $F(X_i) = w_i(c_i-f(X_i))/w_j(c_j-f(X_j))$.

Country output is given by Nq_i. Given the (unchanged) symmetric equilibrium R&D expenditure from equation (16), and given all else is symmetric, $w_i=w_j$ and $F(X_i)=1$. Therefore (25) simplifies to:

$$q = a\phi/4w(c-f(X)). \tag{26}$$

Firm output is increasing in the demand parameter and the substitutability parameter, and decreasing with the wage and unit costs. The labour demand equation gives us a second expression for q:

$$q = L/N(c-f(X)). \tag{27}$$

Equations (26) and (27) solve for the symmetric equilibrium wage, given by (28):

$$w = Na\phi/4L. \tag{28}$$

Equilibrium wages are increasing in the demand parameter, the elasticity of substitution and the total number of sectors, N and decreasing with the size of the labour force. Substituting (28) back into (26) gives country output, Y:

$$Y = L/(c\text{-}f(X)). \tag{29}$$

Costs are reduced in period t, consisting of the research and production stages, through innovation, by f(X). If initial costs at the start of period t are labelled as c then starting costs in period t+1 are c-f(X). So, from (29):

$$Y_t = L/c \quad \text{and} \quad Y_{t+1} = L/(c\text{-}f(X)). \tag{30}$$

The growth rate of country output, for given t, is therefore given by (31).

$$(Y_{t+1} – Y_t)/Y_t = \{[L/(c\text{-}f(X))] – [L/c]\} / [L/c]. \tag{31}$$

Equation (31) simplifies to the following per capita growth rate:

$$g = [c/(c\text{-}f(X)] – 1. \tag{32}$$

Therefore, unsurprisingly, growth is increasing in R&D. It is a small step to substitute the expression for f(X) from (16) into (32) to give per capita growth as a function of the parameters of the model:

$$g = 2/[1 + \sqrt{\{1 - a(1-\beta)(\theta-1)/2\theta\}}] - 1. \quad (33)$$

So, per capita growth is a function $g(a,\beta,\theta)$ with $g'(a)$ and $g'(\theta) > 0$, and $g'(\beta) < 0$.

Growth is driven purely by the endogenous R&D decisions of profit maximising firms. The growth rate is positively related to the degree of integration, solely because of the intensity of competition effect. Although there are scale effects in the model, given by the positive relationship between g and a, this integration/growth result is not related to scale, as the parameter a is assumed constant. In other words, the model shows how the intensity of competition effect of economic integration can be used to obtain a non-scale endogenous growth effect of integration. The intuition for this result and the other results given by (33) is the same as that discussed in Section 3.

Holding all other parameters constant, the productive capability of the whole economy grows over time. In fact, the economy displays a constant growth rate, given by:

$$g = [2/(1+\eta)] - 1, \quad (34)$$

where $\eta \leq 1$.

6: Summary and Concluding Remarks

This paper considers the effects of economic integration on a firm's incentives to innovate starting from the viewpoint of the IO literature concerning innovation and market structure. A model is set up of an industry consisting of two competing firms producing differentiated goods, with deterministic process innovation and knowledge spillovers. Increased competition resulting from integration makes a firm’s market share more sensitive to prices. A symmetric equilibrium results where R&D is increasing with integration. This is because of intensified strategic incentives to both steal the competitor’s market share and to protect own market share. In addition, two special cases of the model are considered. If firms are allowed to co-operate in R&D, the strategic incentives are removed and R&D stops. Secondly, if spillovers are positively related to the degree of integration, then an inverted U-Shaped relationship between integration and R&D is the result, with an optimal level of integration. Finally, the model is extended to an n-sector two-country economy that displays a constant growth rate. This growth rate increases with integration.

Existing models explaining possible mechanisms for a positive link between growth rates and integration are generally driven by improved R&D performance resulting from the scale effects of increasing market size and access to a wider stock of technical knowledge (eg: Rivera-Batiz and Romer, 1991). This paper sets up a model where increased strategic incentives to innovate provide an alternative mechanism to these scale effects through which integration can stimulate R&D.

The model is consistent with the weight of the empirical evidence in the IO literature suggesting a positive relationship between competition and innovation. By adopting a simple extension, the model can also be made consistent with the kind of non-linear relationship found by Scherer (1967). The intensity of competition effects described here may be small compared to the demand-pull and technology-push effects, which is a question best analysed empirically. However, the case for their existence is clear.

Of course, given the somewhat stylised nature of the model, the results should be treated with caution. This paper is intended as a starting point for further research, which can move towards generalising the model. It would be interesting to see if the results hold when the model is extended to an explicit dynamic framework on which a more solid growth model could be built. Alternative forms of competition and innovation (eg: Bertrand and new product) may lead to different conclusions. Clearly this line of research has potential for development.

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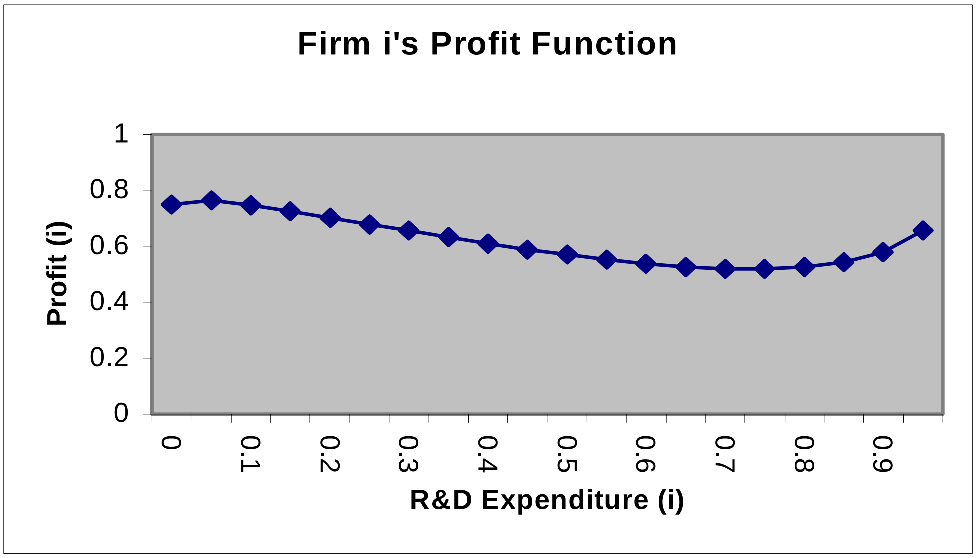
Figure 3.1: Firm i's Profit Function.



Notes: The above function is Equation (15) for parameter values a=2, θ=2, β=0 and x_j=.1.

Table 1: R&D Expenditure with Asymmetric Initial Unit Costs

θ,β	**0**	**.1**	**.5**
2	.027, .018	.021, .016	.010, .005
5	.080, .075	.060, .055	.028, .020
10	.094, .090	.090, .085	.034, .025

Notes: Values of θ=2,5 and 10 represent low, medium and high elasticity of substitutability respectively, and therefore low, medium and high levels of integration. Values of β=0, .1 and .5 represent zero, low and high spillovers. Figures for firm 1 (the high cost firm) are on the left of each cell, with figures for firm 2 on the right of each cell.

Table 2: Stage 2 Unit Costs with Asymmetric Initial Unit Costs

θ,β	**0**	**.1**	**.5**
2	.85, .85	.86, .86	.89, .89
5	.72, .72	.75, .75	.81, .81
10	.70, .70	.70, .70	.79, .79

See notes for Table 1.