Essays on Intellectual Property: Innovation, Growth and Strategies

By

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DEDICATION

This thesis is dedicated to the memory of my father Robert Joseph Collette who has passed on to me the strength, intelligence and perseverance to accomplish any and all challenges that lay before me; and to my wife Rebecca Lynn Dalton for ensuring that I did not lose sight of this over the years.

ABSTRACT

Innovation has become one of the most important policy topics in economics as governments around the world have come to recognize that it is through innovation that long-run economic growth can be sustained. Intellectual property rights play an important role as they provide the necessary incentives for individuals and companies to innovate. The objective of this thesis is to provide theoretical and empirical evidence in three distinct areas related to innovation and intellectual property. The first essay presents a model that provides a theoretical basis for the existence of both large firms and fringe entrepreneurs in the same competitive R&D industry that produces patents. The second essay provides evidence that specific measures of patenting provide a better measure than traditional measures of innovation for productivity analysis. The third essay provides evidence on the strategic use of the trade-mark opposition process as a way of increasing cost to potential entrants and thereby creating a potential barrier to entry.

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PART I

A model of both large and small scale innovation

Abstract: Economies of scale theories suggest that large firms should undertake, over time, an increasing proportion of R&D and by extension patents. However, there has been no increase as predicted, and in some countries small and medium enterprises have actually increased their share of patenting activity. In this paper I present a model that provides a theoretical basis for the existence of both large firms and fringe entrepreneurs, leading small firms, in the same competitive research and development (R&D) industry that produces patents. In a world with decreasing information costs I show that the size of larger research units decreases while the number of research units in the industry increases and, depending on the distribution of the value of the ideas in question, more or less entrepreneurs will leave established firms. I also show the condition whereby the total number of ideas pursued by firms in the industry increase as information costs decrease and that this condition is met with greater likelihood as the optimal size of the firm decreases. Finally the model shows that as information prices decrease there is an increase in the number of entrepreneurs leaving firms to implement ideas.

1 Introduction

The purpose of this paper is to reconcile two seemingly contradictory features of the R&D market for innovation. First, over the last few decades there appears to have been a growth in (or at least not a diminishing of) the share of patents produced by small to medium sized research units in comparison with the share produced by large research establishments (U.S. Small Business Administration, 2003). Second, and at the same time, academic researchers seem to find economies of scale in innovation effort (Lee and Sung, 2005; Tsai and Wang, 2005). Hence why the ability of larger research groupings to internalize joint research benefits does not lead to the production of more and better ideas at lower cost and thus drive out smaller sized rivals is the puzzle that I investigate in the following pages.

The question of the appropriate organizational form, whether large firms, small firms, or individual entrepreneurs are a more efficient source of innovation, has been discussed without a clear resolution since Schumpeter advanced two of his most famous ideas. First, in 1912, he put forward the idea that entrepreneurship is the key needed to ensure high rates of innovation (Schumpeter, 1912/1934). He then later changed his position to one where large firms, using barriers to entry and monopolistic competition, were the key to achieving high rates of innovation (Schumpeter, 1942). Over many years empirical investigations have produced mixed results (see the summary in Nooteboom, 1994). The fact that no definitive answer has emerged suggests that there may be circumstances in which both survive. Recent research, particularly that by Baumol (2004) and Etro (2008), has re-emphasized the theoretical perspective introduced into

the literature by Stigler (1958) that there may co-exist a wide range of optimal firm sizes. There may be a distribution of optimum firm sizes that will respond through time to changes in factor prices or technology because different scales may correspond to the use of different technologies or different types or qualities of resources.

In a recent article Klepper and Thompson (2009) provide an overview of the empirical regularities and theoretical models that have emerged with respect to spin-offs. These empirical regularities include: spin-off rates that first increase with firm age and then decrease (with a maximum occurring at 14 years); spinoff rates often arising with a change in management, either by acquisition or a change in CEO; spinoffs being spawned by better performing firms and performing better, and; internal spin-offs outperform entrants from outside the industry. With respect to theoretical models the Klepper and Thompson (2009) divide these into three broad categories. First are models based on asymmetric information, deceit or poor contract structure. Second are models with symmetric information, but where the large firm feels the idea will cannibalize current rents or is not part of their main activity. An example of this is IBM, who saw both Microsoft and Intel spin-off and become very successful. Third are those models where the employees learn how to be profitable from their employer and carry this knowledge forward. Many of these models attempt to understand the emergence of spinoffs from large firms, and the evolution of industries using new, non-equilibrium based frameworks. Examples include; anchor-tenant models with a single large dominant firm and many small firms (Agrawal, A. and Cockburn, I., 2003), evolutionary or hereditary models based on individuals leaving existing firms and creating a set of small fringe competitors (Klepper and Sleeper, 2005) and cost-spreading models that

consider the size of the product market of the firm, rather than the R&D component (Cohen and Klepper, 1996). A recent model looks into disagreements within a firm over the overall strategic direction of the firm as the mechanism for spin-offs (Klepper and Thompson, 2009).

In this paper I develop a different type of model, based on symmetric information, disagreement and information costs, which explains why spin-offs occur and how small firms and large firms can co-exist within a competitive R&D industry. The model is different in that it moves away from the assumptions of asymmetric information and/or misrepresentation by individuals (Klepper and Thompson, 2009). The R&D unit is the focus of the analysis. I argue that because the market value of early research effort is inherently uncertain, there will always be a positive probability that the researcher and the firm implementing new ideas will disagree on their future value. Under certain conditions this disagreement will be sufficient to lead researchers to become independent entrepreneurs. This is consistent with evidence that points to the fact that disagreement among decision makers about direction of the firm with respect to technology and management often leads to spinoffs (Klepper and Thompson, 2009). There is also evidence of spinoffs commercializing ideas that the parent firm chose not to pursue (Klepper and Sleeper, 2005). Finally, Pakes and Nitzan (1983) show that when set up costs are not too high it is expected that researchers will spinoff ideas when their economic possibilities are relatively unexplored, or, in other words there exist large amounts of uncertainty. The outcome of this situation results in an industry composed of both large scale and small scale innovators. I then show that as the cost of outside information (e.g., generalized knowledge) decreases the optimal size of the

(larger) R&D units fall even as the total number of R&D units in the industry increases. Finally, I present the conditions under which the size of the fringe of individual entrepreneurs increases as information costs fall. With the establishment of the Internet and the advancements in information and communication technology there has been a steady decrease in the cost of creating, storing and transmitting information.

The remainder of the paper is structured as follows. Section 2 provides an overview of the empirical results in this field. Section 3 presents some stylized facts about Canada. Section 4 presents the model. Section 5 provides a brief summary and concluding remarks.

2 Empirical Evidence

We begin by noting that the largest body of literature in the field of industrial organization (Cohen, 1995) concerns the role of firm size in innovative performance. One reason for there being so much work in this area is that there has been no clear resolution of the competing Schumpeterian hypotheses on firm size and market structure within the R&D industry. Even in one of the first, pioneering empirical studies of R&D, the hypothesis that the monopolist was the efficient innovator, as followers of Schumpeter had always supposed it to be, was shown to be doubtful (Scherer, 1965). Since Scherer himself was inclined to believe large firms were the efficient vehicle for innovation, this introduction of doubt was significant. As econometric techniques and data availability improved over the following decades many other economists have tried

their hand at answering the question of whether large firms, small firms, or individual entrepreneurs are the more efficient source of innovation.

On one side some researchers have shown that R&D undertaken and R&D performance both increase as firm size increases (Lee and Sung, 2005; Tsai and Wang, 2005). Other studies have shown that large firms have a greater incentive to perform both process and product R&D and appear more innovative within overall innovative activity (Tether, 1998; Johansson and Loof, 2008; Plehn-Dujowich, 2009). The other side argues that results are not at all clear. For example, a number of studies suggest that once factors such as industry or country effects are accounted for there is little support for increasing returns-to-scale in innovation (Cohen et al., 1987; Arvantis, 1997; Acs and Audretsch, 2001). A final group of studies conclude that there is no unequivocal advantage for either small or large firms in the innovation process, some industries or countries are consistent with a specific return-to-scale hypothesis, while others are not (Levin et al., 1985; Rothwell, 1989; Doi, 1996; Malerba and Orsenigo, 1999; Pianta and Vaona, 2007; Lee and Noh, 2009).

3 Stylized Facts - Evidence from Canada and the U.S.A.

While the empirical literature testing whether large or small firms are more efficient sources of innovation may be inconclusive, the evidence that small firms and entrepreneurs are an important, and in some cases increasing; source of innovation cannot be disputed. A recent U.S. study showed that a small firm patent is twice as likely to be among the top 1% of the most cited patents as a large firm's patent. The

study also showed that small firms are about 13 times more innovative per employee than larger firms and represent a third of the most prolific patenting companies that have more than 15 patents (U.S. Small Business Administration, 2003). A recent Canadian study has shown that the proportion of company revenue spent on R&D expenditure decreased with firm size in Canada (Industry Canada, 2007). An earlier study had come to similar conclusions, noting that innovation was the most important trait associated with success; with possessing an R&D unit and having a higher proportion of R&D to total investment and revenues being key indicators of that success (Baldwin, 1995). Nor is this a new pattern. In a study of the great inventors from 1790 to 1865 in the United States, Khan and Sokoloff (1993) found that many were entrepreneurial, with their inventions being pro-cyclical and originating in areas with extensive market opportunities that were more conducive to commercialization.

Data from the Canadian Intellectual Property Office (CIPO) also provides evidence of the importance of entrepreneurs in innovation. Entrepreneurs, defined as individuals who are both the applicant and the owner of the right to patent at the time of filing, have seen their share of patent grants increase over the period from 1990 to 2009. This is shown in Figure I-1 below¹. Entrepreneurs accounted for over 10% of all applications granted in Canada between 1990 and 2008, demonstrating the importance of this group in the innovation process.

¹ Grants are presented by year of application and not the year they were granted. This is done to ensure that capacity constraints at CIPO do not cloud the results. What this means is that the number of grants in the final years of the data are likely to change as more patents from those years are examined in the future, but early indications are positive.

Figure I-1 Entrepreneur's Grants as a % of Total Patent Grants in Canada

4 The Model

4.1 The firm's problem

I begin with a risk-neutral firm that hires risk-averse researchers. Researchers in the firm are engaged in two activities, either searching for ideas to commercialize or implementing ideas that the firm has deemed to be worth commercializing. Note that for the purposes of this paper, the unit of interest is the R&D unit and the use of the word “firm” in the following refers to an R&D unit. In addition to paying its researchers, the firm faces two other types of costs. The first are the costs of implementing new ideas; transforming an idea from its initial to final stage where the idea has commercial value and is protected in a patent. Prominent among these costs is the cost of acquiring the information needed to implement this transformation. Implementation costs are assumed to enjoy economies of scale, as spillovers in exploration and implementation result in a lower average cost per researcher, n , as the scale of the firm increases.

Information and research are viewed as substitutes so that a reduction in information costs, z , reduces the cost advantage of researchers. At the industry level, however, implementation encounters increasing cost. It may be, for example, that an increase in the number of firms, k , increases the likelihood that ideas may be duplicated, resulting in wasteful research. Alternatively, the price of industry specific resources may be bid up through the competition of entrants. The second set of costs faced by a firm is the cost associated with managing its researchers. As the firm grows larger, the firm must monitor and coordinate the activity of an increasing number of researchers. These costs are assumed to increase at an increasing rate.

The parameters of the model described above are formally present below:

$f(\theta)$: is the frequency of values of θ in the distribution of potential ideas,

θ_c : is the minimum value the firm must expect before implementing the idea,

w : is the exogenous wage rate,

$I(z, n, k)$: is the implementation cost per project of the firm, with the partial derivative properties $I_k > 0, I_z > 0, I_n < 0$ and $I_{nn} > 0, I_{nz} < 0, I_{nk} = 0$,

$t(n)$: is the firm's pre project cost of managing its researchers, with $t_n > 0$ and $t_{nn} > 0$,

n : is the total number of researchers in the firm,

k : is the number of firms in the R&D industry,

z : is the cost of information,

ψ : is the proportion of researchers that are implementing ideas.

Note that:

$I_k > 0$ denotes that implementation costs increase at the industry level;

$I_{nz} < 0$ means that a rise in information costs will increase the economies of scale in additional researchers; and

$I_{nk} = 0$ implies that as firms enter and exit there is no direct effect on the economies of scale within the firm.

Each (otherwise identical) researcher engaged in exploring ideas is assumed to generate one idea per period and the value of the idea drawn can be described as a random drawing from the a distribution of potential ideas

$$\int_0^{\infty} f(\theta) \cdot d\theta. \quad (1)$$

The firm is assumed to hire researchers from a pool of researchers at the competitive wage, w , and owns the right to the revenue stream generated by the idea. This process is viewed as taking place in two stages. In the first stage of the problem, the researcher generates an idea. In the second stage, the idea must be processed into a patent. Hence at the discovery stage, the true value of the idea will be unknown and the firm must form an assessment of the value of the idea explored, so that θ_j is the j^{th} firm's assessment of i^{th} researcher's idea's value. Since all firms are assumed to be identical we drop the j subscript and talk of a representative firm. Similarly, all projects appear as identical random drawings ex ante. The expected value of any randomly drawn project is

$$E(\theta) = \int_0^{\infty} \theta \cdot f(\theta) d\theta. \quad (2)$$

Since an idea needs to be processed into a patent before the idea can be commercialized, the firm will proceed only if it expects the idea explored to cover the cost of implementation. Moreover because the outcome of processing is in the future, at the discovery stage the researcher and the firm can have a difference of opinion over the commercial viability of the particular idea explored. This becomes the basic reason for the emergence of small innovators.

To proceed with implementation a project must be commercially viable. Since the wage paid to discover the idea has already been incurred (and hence is sunk) the firm will continue with the project only if the project is expected to cover the per project implementation and management costs, i.e., if and only if it believes that

$$\theta \geq \theta_c = I(z, n, k) + t(n) + w. \quad (3)$$

Note that the w term in (3) is to pay the researcher to work on implementing the idea. The expected value of a project that proceeds to implementation is

$$E(\theta | \theta \geq \theta_c) = \int_{\theta_c}^{\infty} \theta \cdot f(\theta) d\theta. \quad (4)$$

If $\theta < \theta_c$ then the firm is willing to relinquish its right to patent this idea for any positive payment. This allows the researcher, whose personal assessment of the commercial viability of the project may differ from that of the firm, to acquire the right to patent the idea outside of the firm. The researcher will do so only if they believe the commercial viability of the project exceeds the costs of implementing outside of the firm, plus a risk premium amount due to their risk aversion. This problem is formally analyzed later.

Although the question of how the payment from the researcher to the firm is determined is of interest it is not considered formally in the model presented below. Rather, I assume that the ideas considered to be of no commercial value are sold for any positive payment. Alternatively, the firm has taken future potential profits, which are part of the bargaining process, into consideration when formulating its expected value of the project expressed in equation (4).

In any period of time, a researcher will perform one of two jobs in the firm. Either they are exploring for ideas or they are implementing successful ideas. If a researcher's idea is selected for implementation, the researcher then turns from search to implementation. On the other hand, if their idea is rejected for implementation, the researcher will continue to search for new ideas². It follows that across time, there will be one proportion of the group of researchers exploring new ideas and another proportion implementing ideas discovered in the recent past. Although the individual composition of the groups will change over time, a steady state division can be derived directly from the probability that a given idea will be selected for implementation.

To illustrate how convergence to the steady state distribution will take place, let ϕ be the probability that a randomly chosen project will be chosen for implementation.

That is, given θ_c let

$$\phi = \int_{\theta_c}^{\infty} f(\theta) \cdot d\theta. \quad (5)$$

² In the case where researchers make a positive payment to the firm to acquire the right to the idea and leave to implement it outside the firm, the firm hires a replacement to continue the search for new ideas. Since we assume that all researchers are identical ex ante, their replacement leaves the firm's choice problem unaltered.

Then starting from an initial position where all researchers are hired to seek new ideas in period t , ϕ is the probability that an idea discovered in period t will be selected for implementation in period $t+1$. This implies that ϕ is the probability that a randomly chosen researcher in period t will be implementing their discovered idea in $t+1$. Normalizing the number of researchers to one, I can express the proportion of researchers implementing ideas in the second period as ϕ and the proportion who continue exploring ideas as $(1 - \phi)$.

In period $t+2$, those researchers who were implementing ideas in period $t+1$ will return to the pool of researchers exploring new ideas. As such they will join those researchers who were unsuccessful in their search for commercially valuable ideas in period $t+1$. Hence the proportion of researchers who will be exploring for ideas in period $t+2$ is

$$\phi + (1 - \phi)^2 = 1 - \phi + \phi^2. \quad (6)$$

Since the total is 1, the proportion of researchers who are expected to be implementing ideas in the same period is

$$1 - (1 - \phi + \phi^2) = \phi - \phi^2. \quad (7)$$

If I continue to expand the number of steps and follow the resulting pattern³ it can be seen that as the number of periods increases towards infinity, the proportion of researchers exploring ideas will converge on

$$\sum_{i=0}^{\infty} (-1)^i \phi^i = 1 - \phi + \phi^2 - \phi^3 + \dots + \phi^{\infty} = \frac{1}{1 + \phi}. \quad (8)$$

³ To continue for one more period, the number of researchers who will be exploring for ideas in period 4 will be those who were implementing in the previous period, $\phi - \phi^2$, plus the number who are expected to be unsuccessful searchers that period $(1 - \phi + \phi^2)(1 - \phi)$. This equals $(1 - \phi + \phi^2 - \phi^3)$.

Hence if I focus on the steady state, the expected proportion of researchers who will be exploring for ideas is

$$\frac{1}{1+\phi} \quad (9)$$

and the expected proportion of researchers implementing ideas is

$$1 - \frac{1}{1+\phi} = \frac{\phi}{1+\phi}. \quad (10)$$

For notational convenience I denote the proportion of researchers implementing ideas in the steady state as

$$\psi = \frac{\phi}{1+\phi} \quad (11)$$

and by extension the number of researchers exploring for ideas in the steady state is

$$1 - \psi = \frac{1}{1+\phi}. \quad (12)$$

By focusing on the steady state and making comparisons across steady states I am abstracting from the transition process. Hence to give some feeling for the time needed for the process outlined above to converge to the steady state, I present a series of simulations. The value distribution of discovered ideas is known to be highly skewed (Harhoff et al, 1999; Silverberg and Verspagen, 2007), with very few higher value ideas and many more with lower value. Hence I do not expect to have more than half of all newly discovered ideas implemented each period.

Figure I-2 illustrates quite dramatically that even when the probability of having an idea accepted rises as high as 50%, the proportion of researchers implementing ideas converges on the steady state value of 33.3% within six periods. In the more likely cases where the probability of implementation is as low as 10% or 20%, the series

converges as early as the second or third period. Hence by focusing on the steady state we are unlikely to be avoiding a significant part of the analysis.

Figure I-2 Simulation of Convergence

It follows that in the steady state, a firm with n total researchers will expect to find only a fraction of that total in the search for new ideas. In particular, the expected number of researchers exploring for ideas will be

$$\frac{n}{1+\phi}. \quad (13)$$

Given that only the fraction $(1-\phi)$ of each discovered idea will be judged capable of being implemented, $\frac{n(1-\phi)}{1+\phi}$ ideas will be judged to be commercially unsuccessful each period. It follows that if there are k firms of similar size in the industry, the expected number of rejected ideas per period will be

$$E(\# \text{ of rejected ideas}) = \frac{n \cdot k}{1+\phi} \cdot (1-\phi). \quad (14)$$

This is increasing in n and k , and decreasing in ϕ .⁴

A firm can continue to survive in the industry producing new ideas only if it is able to assess correctly the commercial value of the ideas explored by researchers on average. Hence the representative firm will be assumed to be correct in its assessment on average. This does not mean that it cannot make an occasional error in judgement. It does follow however, that if the R&D industry producing patents through ideas is competitive, entry by similar firms will take place as long as abnormal profits can be realized. Given our discussion, the steady state expected profit function, π , of the representative firm can be described as

$$\pi(z, n, k) = n\psi \left[\int_{\theta_{c, t-1}}^{\infty} f(\theta)(\theta) \cdot d\theta - I(z, n, k) - t(n) - w \right] - n(1 - \psi)w. \quad (15)$$

The first term on the right hand side is the profit expected from implemented ideas. That is, it is the expected revenue of the ideas selected for implementation less the costs of their implementation, coordination, and labour. The second term is the fraction of the wage bill associated with the researchers exploring for new ideas. The steady state profit stream will equal the net of these two terms.

By taking the wage bill for the implementers outside of the bracket, the two portions of the wage bill can be combined to obtain a simplified steady state expected profit function

$$\pi(z, n, k) = n\psi \left[\int_{\theta_c}^{\infty} f(\theta)(\theta) \cdot d\theta - I(z, n, k) - t(n) \right] - nw. \quad (16)$$

⁴ $\frac{\partial E(\cdot)}{\partial \phi} = -\frac{2n \cdot k}{(1 + \phi)^2} < 0$

To describe the steady state of this industry we begin by describing the condition that determines the optimal number of firms, k . That is, given that the firm is employing the appropriate number of researchers, n^* , entry or exit will arise if profits are nonzero. In the case of positive (negative) profits, entry (exit) will occur and k will increase (decrease) until the rising (falling) average cost of implementation reduces (raises) profits to zero. When the zero expected profit condition is met, k is at its steady state value k^* . This implies that at n^*, k^*

$$n^* \psi \cdot \left(\int_{\theta_c}^{\infty} f(\theta)(\theta) \cdot d\theta - I(z, n, k^*) - t(n) \right) - n^* w = 0. \quad (17)$$

To interpret this condition for the firm in steady state, we divide through by number of implementers to get

$$\psi \cdot \left(\int_{\theta_c}^{\infty} f(\theta)(\theta) \cdot d\theta - I(z, n, k^*) - t(n) \right) - w = 0. \quad (18)$$

This states that the net expected return from each hiring and each potential idea must be zero. This implies that the net profit produced from each implemented idea must be positive enough to generate the extra revenue needed to compensate for the cost of having to hire those additional workers whose ideas will, randomly, not turn out to be implementable. The second term is treated differently to account for the fact that for each idea actually implemented there must be a proportionally larger number of ideas generated. The per-unit wage bill must then include all the necessary researchers in the firm, not only those implementing ideas.

Next to determine the optimal scale of the research unit, n^* , the firm is assumed to take industry size, k , and the proportion to be implementing ideas ψ as given and then

choose the n that maximizes expected profit in (16). Hence the firm's first order condition for expected profit maximization is

$$\frac{\partial \pi(z, n, k)}{\partial n} = \psi \left[\int_{\theta_c}^{\infty} f(\theta)(\theta) \cdot d\theta - I(z, n, k) - t(n) - w \right] - n\psi \cdot f(\theta_c) \frac{\partial \theta_c}{\partial n} \theta_c - n\psi(I_n + t_n) = 0. \quad (19)$$

Recognizing the first term as zero expected profit condition for the market expressed in (18) and replacing θ_c and the change in θ_c with the respective expressions yields

$$\frac{\partial \pi(z, n, k)}{\partial n} = -n\psi \cdot f(\theta_c)(I_n + t_n)(I + t + w) - n\psi(I_n + t_n) = 0. \quad (20)$$

Rearranging and simplifying equation (20)

$$\frac{\partial \pi(z, n, k)}{\partial n} = -n\psi \cdot (I_n + t_n)[f(\theta_c)(I + t + w) - 1] = 0. \quad (21)$$

Now the final term is positive (given that the values of I , t and w are understood to be large). We can then divide both sides by that term n and ψ out to obtain our first order condition

$$\frac{\partial \pi(z, n, k)}{\partial n} = -(I_n + t_n) = 0. \quad (22)$$

Then for $n^* > 0$ this implies

$$t_n = -I_n. \quad (23)$$

The first order condition reflects the decision by the firm to increase n as long as marginal benefit received from the economies of scale in implementation exceeds the rising marginal coordination cost of hiring an additional researcher and so increasing firm size. At the optimum the two must be equal.

For (22) to represent profit maximization, the second order condition must hold.

The second order condition for (16) is

$$\frac{\partial^2 \pi(z, n, k)}{\partial n^2} = -\psi \cdot (I_n + t_n) [f(\theta_c)(I + t + w) - 1] - n\psi \cdot (I_{nn} + t_{nn}) [f(\theta_c)(I + t + w) - 1] - n\psi \cdot (I_n + t_n) [f(\theta_c)(I_n + t_n)] = 0. \quad (24)$$

Now since $(I_n + t_n) = 0$, the first and third terms disappear, leaving

$$\frac{\partial^2 \pi(z, n, k)}{\partial n^2} = -n\psi \cdot (I_{nn} + t_{nn}) [f(\theta_c)(I + t + w) - 1] < 0. \quad (25)$$

We can divide through by the positive n and ψ , and with earlier assertion that

$f(\theta_c)(I + t + w) > 1$ we can divide through that term as well, leaving

$$\frac{\partial^2 \pi_i(z, n, k)}{\partial n_i^2} = -(I_{nn} + t_{nn}) < 0. \quad (26)$$

Since I_{nn} and t_{nn} are both positive, the solution is indeed a maximization.

Equations (18) and (22) then define a competitive steady state in the industry implementing patentable ideas. The steady state implies a solution for n^* , k^* , and a certain fraction of explored ideas that are discarded each period, Ψ , given the values of the model's exogenous parameters: z , w , the distribution of potential ideas, $f(\theta)$ and the forms of the two cost functions $I(\cdot)$ and $t(\cdot)$.

4.2 The researcher's problem

I have assumed that researchers are risk-averse individuals who choose to work for a research firm that promises them w each period with certainty. On the other hand, if the firm rejects their idea as uneconomic while their expectation of the value of their discovered idea is sufficiently high, researchers could choose to pay the firm a lump sum for that project potential and implement the idea themselves. In this case they own the

profits generated from the project while they bear the full cost of implementing and commercializing their project. For these researchers, a project becomes feasible only if in their opinion the expected return exceeds their costs

$$E(\theta_i) > \theta_R = I(z, 1, k) + t(1) + \Theta. \quad (27)$$

Where $\Theta = w + \gamma$ and γ is the lump sum payment needed to acquire the idea judged by the firm to be non-implementable.

To incorporate the researcher's risk-aversion into their choice problem, I assume that the researcher's utility function exhibits constant absolute risk aversion (CARA). The behaviour hypothesis associated with CARA utility functions has been argued as appropriate to small decision makers with common wealth levels by Escalante and Rejesus (2008).⁵ One important characteristic of this type of utility function is that the risk-premium, measured by variance, is a constant. In our problem we denote that constant risk premium as ε . Hence by incorporating the risk premium, (27) can be made more precise and re-written as

$$E(\theta_i) > \theta_R^* = I(z, 1, k) + t(1) + \Theta + \varepsilon, \quad (28)$$

where

$$\theta_R^* \geq \theta_R + \varepsilon. \quad (29)$$

From this it follows that the researcher's decision to leave the firm can be written as the decision rule, leave if and only if

$$U(E(\theta_i) - I(z, 1, k) - t(1) - \gamma - \varepsilon) > U(w). \quad (30)$$

⁵ Although one of the implications of CARA utility functions is that wealth does not matter, this is also the main criticism of the use of CARA utility functions. That is, wealth levels should have an impact on risk-aversion. If a model is considering small decision makers who have common wealth levels then the criticism is no longer warranted. This allows us to state that any negative implications of considering CARA utility functions do not apply in this case.

In other words for the research to spin-off the research project, the utility expected from implementing the idea, defined as the utility generated by the idea's expected revenue less implementation cost, the lump-sum acquisition payment, and the risk-premium must be greater than the utility of remaining in the firm and receiving the steady state wage. Given that the researcher's beliefs are generated as a random drawing from the original distribution of potential outcomes, the probability that the researcher will think that the project is worth spinning off is

$$P(R) = \int_{\theta_R^*}^{\infty} f(\theta) d\theta = P[E(\theta_i) > \theta_R^* = I(z, 1, k) + t(1) + \Theta + \varepsilon]. \quad (31)$$

Since I_z is negative we expect that a decrease in the price of information will always increase the number of projects that just meet the leave criteria and hence increase the probability that the research will pay for the right to the idea and spin-off from the firm.

4.3 Combining the two decisions

Given that at the discovery stage researchers can have different beliefs about the viability of a given project than does the firm, cases arise where $E(\theta_i) \geq \theta_R^*$ and $\theta_C \geq \theta_{ij}$. In these cases the firm is not interested in pursuing the commercialization of the project, but the researcher believes that the project is worth commercializing and will leave the firm to do so.

The question of interest is how likely is this event? Given that the two sets of beliefs are formed independently, the likelihood that the firm will reject any randomly

drawn idea and the researcher will choose to implement the idea himself is the joint probability problem

$$P(C \cap R) = P(C) \cdot P(R), \quad (32)$$

or, more formally,

$$P(C \cap R) = \int_0^{\theta_C} f(\theta) d\theta \cdot \int_{\theta_R^*}^{\infty} f(\theta) d\theta. \quad (33)$$

Figure I-3 The Distribution of Project Values

I define

$$\theta_C(z, n, k) = I(z, n, k) + t(n) + w \quad (34)$$

and

$$\theta_R^*(z, n, k) = I(z, 1, k) + t(1) + \Theta + \varepsilon. \quad (35)$$

This means that

$$P(C \cap R) = P(z, n, k) = \left[\int_0^{\theta_C(z, n, k)} f(\theta) d\theta \right] \cdot \left[1 - \int_0^{\theta_R^*(z, 1, k)} f(\theta) d\theta \right]. \quad (36)$$

4.4 The effects of a change in the price of information on the steady state of the firm

Given the above I can now solve for the changes in the steady state that are implied by a change in one of the exogenous variables, such as a change in information costs. For such a change we need to solve for the simultaneous change in both n and k from (18) and (22) and then see what is the impact for the change in θ_C .

For a change in information costs z , we first take the total derivative of (18) with respect z to find

$$-\psi \cdot f(\theta_C) \frac{\partial \theta_C}{\partial z} \theta_C - \psi \cdot \left(I_n \frac{dn^*}{dz} + t_n \frac{dn^*}{dz} + I_k \frac{dk^*}{dz} + I_z \right) = 0. \quad (37)$$

Substituting for θ_C and the change in θ_C with the respective expressions and rearranging yields

$$-\psi [f(\theta_C)(I + t + w) - 1] \cdot \left(I_n \frac{dn^*}{dz} + t_n \frac{dn^*}{dz} + I_k \frac{dk^*}{dz} + I_z \right) = 0. \quad (38)$$

Dividing out the positive second term, as asserted above, and by ψ and grouping terms gives

$$\frac{dn^*}{dz} (I_n + t_n) + \frac{dk^*}{dz} \cdot I_k + I_z = 0. \quad (39)$$

From (22) above, the first term in can be recognized as the firm's first order condition so that (39) reduces to

$$\frac{dk^*}{dz} \cdot I_k = -I_z. \quad (40)$$

This gives

$$\frac{dk^*}{dz} = -\frac{I_z}{I_k} < 0. \quad (41)$$

Next, taking the derivative of (22) at n^*, k^* with respect z , we find

$$I_{nn} \frac{dn^*}{dz} + t_{nn} \frac{dn^*}{dz} + I_{nk} \frac{dk^*}{dz} + I_{nz} = 0. \quad (42)$$

Grouping terms and recognizing that $I_{nk} = 0$ gives

$$\frac{dn^*}{dz} (I_{nn} + t_{nn}) + I_{nz} = 0. \quad (43)$$

Finally, rearranging gives

$$\frac{dn^*}{dz} = \frac{-I_{nz}}{(I_{nn} + t_{nn})}. \quad (44)$$

Now, from the second order condition and that fact that $I_{nz} < 0$,

$$\frac{dn^*}{dz} > 0. \quad (45)$$

The result is that as the price of information decreases, the profit of each of the existing firms will increase and lead to the entry of new firms. This can be seen directly from (41). However, from equation (45) we can also see that the size of the optimal firm, measured in number of researchers, will decrease as the price of information decreases.

4.5 The effect of a change in the price of information on the number of entrepreneurs

I can now consider the effect of a decrease in information costs on the structure of R&D industries that patent. The primary effect arises in response to changes in θ_C and θ_R . In each case the lowering of information costs lowers these values. Note that the changes described here are not in the steady state and therefore are not equal to zero. This will be part of a new steady state where the firm and individual will be taking θ_C and θ_R as given. The result is that in the steady state the firm will be less likely to reject any given project, but the researcher will be more likely to believe that these projects are commercially viable. To investigate this I take the derivative of (36) with respect to z , which yields

$$\frac{\partial P}{\partial z} = \left\{ \left[f(\theta_C) \cdot \frac{\partial \theta_C}{\partial z} \right] \cdot \int_{\theta_R^*(z,1,k)}^{\infty} f(\theta) d\theta \right\} - \left\{ \left[f(\theta_R^*) \cdot \frac{\partial \theta_R^*}{\partial z} \right] \cdot \int_0^{\theta_C(z,n,k)} f(\theta) d\theta \right\}. \quad (46)$$

By assumption, a change in prices relatively benefits smaller firms more than larger firms

$$\frac{\frac{\partial \theta_R^*}{\partial z}}{\frac{\partial \theta_C}{\partial z}} > 1. \quad (47)$$

When the price of the information inputs decreases the probability of the researcher leaving increases

$$\frac{\partial P}{\partial z} < 0. \quad (48)$$

This implies

$$\left[f(\theta_C) \cdot \frac{\partial \theta_C}{\partial z} \cdot \int_{\theta_R^*(z,1,k)}^{\infty} f(\theta) d\theta \right] - \left[f(\theta_R^*) \cdot \frac{\partial \theta_R^*}{\partial z} \cdot \int_0^{\theta_C(z,n,k)} f(\theta) d\theta \right] < 0. \quad (49)$$

Dividing both sides $\frac{\partial \theta_C}{\partial z}$ gives

$$\left[f(\theta_C) \cdot \int_{\theta_R^*(z,1,k)}^{\infty} f(\theta) d\theta \right] - \left[f(\theta_R^*) \cdot \frac{\frac{\partial \theta_R^*}{\partial z}}{\frac{\partial \theta_C}{\partial z}} \cdot \int_0^{\theta_C(z,n,k)} f(\theta) d\theta \right] < 0. \quad (50)$$

Rearranging and solving the integrals

$$\frac{\frac{\partial \theta_R^*}{\partial z}}{\frac{\partial \theta_C}{\partial z}} > \frac{1 - F(\theta_R^*)}{F(\theta_C)} \cdot \frac{f(\theta_C)}{f(\theta_R^*)}. \quad (51)$$

From (47) I assert

$$\frac{1 - F(\theta_R^*)}{F(\theta_C)} \cdot \frac{f(\theta_C)}{f(\theta_R^*)} < 1. \quad (52)$$

Simplifying I obtain

$$\frac{f(\theta_R^*)}{1 - F(\theta_R^*)} > \frac{f(\theta_C)}{F(\theta_C)}. \quad (53)$$

The left hand side of (53) is the hazard rate of the researcher leaving the firm. It is the instantaneous rate of leaving for a change in θ_R^* . The hazard function can be used to approximate a conditional probability of the researcher leaving given a specific change in θ . In the same way the right hand side of the equation is the hazard rate of the firm deciding to not proceed with a given project. It is the instantaneous rate of refusal per θ . If the left hand side of the equation is greater than the right hand side then more

researchers are emerging from firms than number of additional ideas that firms will go forward with due to the decrease in costs. These researchers will then be considered entrepreneurs as they move forward with the idea.

4.6 Changes in the total number of ideas implemented given a change in the price of information

I am next interested in whether a decrease in information costs will lead to a greater or lesser number of ideas being implemented within the R&D industry. To see this we start with our earlier expression for the expected number of rejected ideas each period, equation (14),

$$E(\# \text{ of rejected ideas}) = \frac{n \cdot k}{1 + \phi} \cdot (1 - \phi). \quad (54)$$

Taking the total derivative of (54) with respect to z

$$\frac{\partial E(\cdot)}{\partial z} = \frac{\partial n}{\partial z} \left[\frac{k \cdot (1 - \phi)}{(1 + \phi)} \right] + \frac{\partial k}{\partial z} \left[\frac{n \cdot (1 - \phi)}{(1 + \phi)} \right] + \frac{\partial \phi}{\partial z} \left[\frac{-2nk}{(1 + \phi)^2} \right]. \quad (55)$$

Now, taking the derivative of equation (5) with respect to z

$$\frac{\partial \phi}{\partial z} = \frac{\partial \left(\int_{\theta_{c,t-1}}^{\infty} f(\theta) \cdot d\theta \right)}{\partial z} = -f(\theta_c) \frac{\partial \theta_c}{\partial z}. \quad (56)$$

Subbing (56) into (55) gives

$$\frac{\partial E(\cdot)}{\partial z} = \frac{\partial n}{\partial z} \left[\frac{k \cdot (1 - \phi)}{(1 + \phi)} \right] + \frac{\partial k}{\partial z} \left[\frac{n \cdot (1 - \phi)}{(1 + \phi)} \right] + \frac{\partial \theta_c}{\partial z} \left[\frac{2f(\theta_c) \cdot nk}{(1 + \phi)^2} \right]. \quad (57)$$

The first term on the right-hand side is the change in the number of ideas rejected for implementation resulting from a change in the number of researchers in the firm.

This term is positive, meaning that if information costs go up more researchers will be hired and hence more ideas will be rejected for implementation per firm. The second term on the right-hand side is the change in the number ideas rejected for implementation resulting from a change in the number of firms in the industry. This term is negative, that is, if information costs go up profitability will fall and firms will leave the industry. For this reason the number of ideas that will be rejected for implementation will decrease. The third term on the right-hand side is the change in the number of ideas rejected for implementation resulting from a change in the minimum expected value of a project required to proceed to implementation. This term is positive meaning that an increase in information costs increases the expected value of a project that is required to proceed to implementation. For this reason more projects will be rejected for implementation.

For a decrease in the price of information to result in an increase in the number of ideas accepted, we need (57) to be positive. That is, we need a condition for

$$\frac{\partial E(\cdot)}{\partial z} > 0, \quad (58)$$

or,

$$\frac{\partial n}{\partial z} \left[\frac{k \cdot (1-\phi)}{(1+\phi)} \right] + \frac{\partial k}{\partial z} \left[\frac{n \cdot (1-\phi)}{(1+\phi)} \right] + \frac{\partial \theta_c}{\partial z} \left[\frac{2f(\theta_c) \cdot nk}{(1+\phi)^2} \right] > 0. \quad (59)$$

Multiplying both sides of (59) by the positive term $\frac{(1+\phi)}{nk(1-\phi)}$ gives

$$\frac{\partial n}{\partial z} \cdot \frac{1}{n} + \frac{\partial k}{\partial z} \cdot \frac{1}{k} + \frac{\partial \theta_c}{\partial z} \left[\frac{2f(\theta_c) \cdot nk}{(1-\phi^2)} \right] > 0. \quad (60)$$

Taking the total derivative of θ_c with respect to z

$$\frac{\partial \theta_c}{\partial z} = I_n \frac{dn}{dz} + t_n \frac{dn}{dz} + I_k \frac{dk}{dz} + I_z. \quad (61)$$

From equation (31) above I can simplify to get

$$\frac{\partial \theta_c}{\partial z} = \frac{dn}{dz} (I_n + t_n). \quad (62)$$

Use of the relationship between $\frac{\partial \theta_c}{\partial z}$ and $\frac{\partial n}{\partial z}$ in (60) gives

$$\frac{\partial n}{\partial z} \cdot \frac{1}{n} + \frac{\partial k}{\partial z} \cdot \frac{1}{k} + \frac{\partial n}{\partial z} \cdot \frac{1}{n} \left[\frac{2f(\theta_c)(I_n + t_n) \cdot n}{(1 - \phi^2)} \right] > 0. \quad (63)$$

Grouping terms gives

$$\frac{\partial n}{\partial z} \cdot \frac{1}{n} \left[1 + \frac{2f(\theta_c)(I_n + t_n) \cdot n}{(1 - \phi^2)} \right] + \frac{\partial k}{\partial z} \cdot \frac{1}{k} > 0. \quad (64)$$

Subtracting the second term from both sides of the equation

$$\frac{\partial n}{\partial z} \cdot \frac{1}{n} \left[1 + \frac{2f(\theta_c)(I_n + t_n) \cdot n}{(1 - \phi^2)} \right] > -\frac{\partial k}{\partial z} \cdot \frac{1}{k}. \quad (65)$$

Dividing both sides by the positive term $\frac{\partial n}{\partial z} \cdot \frac{1}{n}$ and rearranging yields

$$-\frac{\frac{\partial k}{\partial z} \cdot \frac{1}{k}}{\frac{\partial n}{\partial z} \cdot \frac{1}{n}} < 1 + \frac{2f(\theta_c)(I_n + t_n) \cdot n}{(1 - \phi^2)}. \quad (66)$$

The left hand side of equation (66) is the elasticity of substitution between the increase in ideas rejected for implementation from the increase in firms in the industry and the decrease in ideas rejected for implementation from the decrease in firm size.

Formally this can be expressed as

$$-\frac{\frac{\partial k}{\partial z} \cdot \frac{1}{k}}{\frac{\partial n}{\partial z} \cdot \frac{1}{n}} = \xi_{kn}. \quad (67)$$

The second term provides insight into how this relationship changes as the price of information changes. The above discussion is between steady states and therefore $(I_n + t_n) \neq 0$. If we are considering a decrease in the price of information then we expect that n is above optimal. That is, as z decreases so should n . This means that the marginal benefit from economies of scale is less than the marginal transaction costs of hiring an additional researcher,

$$I_n < -t_n,$$

$$\text{or,} \quad (68)$$

$$I_n + t_n < 0. \quad (69)$$

The remaining terms on the right hand side are positive, which means that the entire second term is negative. This means that the sufficient condition for a decrease in the price of information to result in an increase in the total ideas accepted for implementation in the industry is

$$\xi_{kn} < 1. \quad (70)$$

In words, the negative effect of the entrance of new firms must be no more than the positive effect of the reduction in firm size. Alternatively, the industry must be growing in the total number of researchers.

5 Conclusion

The model derived above provides a theoretical basis for the existence of both large firms and fringe entrepreneurs in the same competitive R&D industry that produces patents. I have shown that in a world with decreasing information costs circumstances exist in which the size of larger research units will decrease while the number of research units in the industry increases and, depending on the distribution of the value of the ideas in question, more or less entrepreneurs will leave established firms. I have also shown the condition whereby the total number of ideas pursued by firms in the industry will increase as information costs decrease. I have also shown that there is a greater likelihood that this condition will be met when the optimal size of the firm decreases. Finally, the analysis predicts that, *ceteris paribus*, as the price of information decreases there will be an increase in the number of entrepreneurs leaving firms to implement ideas.⁶

A failure in the market for knowledge, both in the production of knowledge and in the level of investment needed to produce knowledge output suggests that policy choices that increase the effort to transform ideas into economically valuable knowledge will be welfare improving (Arrow, 1962; Baumol 2004; Etro, 2008). Hence one policy conclusion that arises from this analysis is that efforts to reduce the cost of information inputs into innovation, including, the transmission of existing knowledge, will under plausible circumstances lead to an increase the number of ideas that reach

⁶ The analysis does not consider upstream research units within established large firms and therefore does not consider production or marketing within large firms, both of which are important. However, my model does allow for firms of many sizes to operate in the market and it is this size variation that determines the number of research units in the firm. It is also possible that a firm may be engaged only in R&D and could license or sell their patented idea to other firms, who may or may not themselves be engaged in R&D in the same technology space, for production.

commercialization. Examples of such efforts include the subsidization of improved networks to allow for easier transmission of large data sets and real time co-research and, increasing the accessibility to innovation based data sets, including patent databases. Ideally these policies would not be targeted, but broader based so that they provide economy wide benefits. Because the smaller sized firms would benefit more proportionally from the effort, they need not be targeted. In this sense the policy would be Pareto improving. The recent collaboration between Google and the United States Patent and Trade Mark Office (USPTO) is an example of just such an initiative.

This study focuses on only one of perhaps many reasons for why small firms can coexist in a competitive industry with larger rivals. Its analysis is then applicable primarily to those industries with a higher propensity to patent, where the ideas to be patented are truly novel and where potential disagreement on future commercial viability is more likely. What preserves the fringe of smaller firms is that other large research firms do not have an option to purchase the disputed idea. This is a reflection of the idiosyncratic nature of specialized expertise that limits the appropriability of original ideas (Cohen and Klepper 1996). Utilizing this special environment, this study contributes to the literature on spin-offs and optimal firm size by providing a model where, absent asymmetric information, individuals will leave larger firms with that firm's consent and co-exist in a competitive environment.

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PART II

Patent families as a measure of innovation that leads to economic growth

Abstract: Innovation is understood to be an important factor in long-run economic growth. There have been many attempts to identify a measure for innovation that performs well in macroeconomic growth models. A number of different patent measures have been considered over the years. I use a new data set on patent families and more specifically, foreign oriented patent families, to test whether this new measure of patenting is a useful proxy for the type of innovative activity that leads to economic growth. I use panel data models and co-integration models where I regress this new patenting measure along with the traditional Solow variables, a measure of human capital and more recent explanatories of growth, on labour productivity. My results show that while traditional investment is the most important determinant of labour productivity, innovative knowledge also plays an important role in the long-run economic growth. I conclude that foreign oriented patent families perform well as a measure for innovative inputs.

1 Introduction

The study of economic growth, or growth theory, and its empirics generates strong interest while posing some of the most challenging problems for economists. Growth theory is of interest primarily because producing a continued increase in the standard of living is often a key objective given to governments by their citizens. It is challenging because globalization has removed availability of production inputs and skill differences as binding constraints on progress such that most developed nations must now rely on continuing innovation simply to remain competitive vis-à-vis their peers (Castellacci, et al 2005). For many developing economies, the ability to exploit existing opportunities means that capital accumulation plays an important role for growth. However, as opportunities for existing economies of scale are realized within the developed world, diminishing returns imply that higher standards of living can be maintained only through innovation and technical change. Hence having been the most robust determinant of growth, capital accumulation in itself cannot sufficiently explain current economic growth or productivity gains (Levine and Renelt, 1992). This has been especially true over the past two decades.

The contribution of this chapter is to consider whether patent data can provide an improved measure of the contribution of innovation, or the production of knowledge, to labour productivity. Specifically, I propose the use of patent families and foreign oriented patent families as more precise measures of commercially valued innovation than traditional patent data. Using this new data I explore whether a refinement in how patent data is understood can result in an improved determination of labour productivity

growth. With the issue of endogeneity receiving greater attention in growth models, special consideration will be given to the use of instrumental variables in panel models and techniques in dynamic co-integration models. Section 2 discusses the use of patent data in growth models. Section 3 provides a literature review of the evolution of innovation in growth theory. Section 4 provides the base model for empirical analysis. Section 5 describes the data and methodology. Section 6 reports the results and section 7 concludes.

2 Patents in Growth Models

The recent explosion in patenting activity (Hall, 2004) presents an opportunity to use patent data to describe technical change and in doing so better capture some elements of this phenomenon. A simple charting of country growth rates, between 1995 and 2006 of gross national product (GNP), against a measure of the growth of patenting within a set of Organization for Economic Co-operation and Development (OECD) countries suggests the plausibility of this approach (figure II-1, Data from OECD and World Intellectual Property Organization (WIPO)). As indicated by the upward sloping regression line on that diagram, there is a clear positive relationship arising between the two.

Figure II-1 Patenting Growth and Labour Productivity Growth 1996-2006

Conceptually the granting of a patent poses a trade-off between the incentives to innovate, provided to the patent holder, by the right to excluded others from using its benefits without compensation, and the deadweight costs arising from the use of monopoly power generated by the same exclusivity. Empirically, however, little evidence exists to validate the notion that the trade-off between inefficiency and technological progress has been beneficial and has resulted in the expected long-run growth suggested by authors such as Arrow (1962) and Nordhaus (1969). This lack of evidence (Crosby 2000 and Hu and Png, 2010), has resulted in an interesting and sometimes heated policy debate over whether patents actually result in more innovation and by extension whether patents contribute to economic growth (Hall, 2007; Boldrin and Levine, 2009). This, in turn, has led to the question of whether patent data is an appropriate measure of innovation. The objective of this paper is to show that patents increase innovation and therefore that they are a good measure of innovation.

While it has been argued that patents measure the flow of new ideas (Jaffe and Trajtenberg, 1998), patents may not measure innovation for four important reasons: patents do not cover non-patented innovations; not all patents result in commercialization; many patents are strategic in nature (Kleinknecht et al., 2002); and patenting levels vary greatly across industries (Aghion et al., 2005). In this chapter, I consider a number of patent measures but focus finally on foreign-oriented patent families as a measure of innovation. The strength of this measure as a measure of innovation is that to be considered foreign-oriented, a patent must be filed in at least two countries. This makes it more likely that these patent families will be higher-valued inventions and inventions that the firm expects to commercialize (OECD, 2012).

An alternative measure of patenting that has gained prominence in the literature is citation weighted patents. The first patent citation database comprised of detailed information on almost 3 million U.S. patents granted between January 1963 and December 1999 and over 16 million citations made to these patents between 1975 and 1999 (Hall, Jaffe and Trajtenberg, 2001). Although of interest as a way of targeting more commercially successful patents, this type of data was not used here for two reasons. The first is because the patent citation database is not truly international in nature. The above mentioned database includes only those patents granted in the U.S., which creates a bias as it is understood that companies are more likely to cite patents in their own country (Roach and Cohen, 2010). Other citation based databases are either limited in their geographic coverage or limited in the number of years of data for some countries. Second, and perhaps more importantly, a firm's citations may be a better indicator of patenting practices designed to delimit the scope of the claims in a patent,

rather than linked to any genuine flow of new knowledge (Roach and Cohen, 2010). Foreign oriented patent families cover more countries consistently, are likely to have less of a home country bias, and are less likely to be impacted by strategic patenting behaviour.

One of the challenges presented is that many innovations or inventions remain hidden as trade secrets. This means that these innovations will be missed in a measure that includes only patents. However, a recent study (Hanel, 2008) indicates that world-first innovators patent more frequently or, conversely, those that patent infrequently tend to be imitators. In addition, the study finds that firms that protect their intellectual property are more likely to increase their profits than those that do not. These conclusions are reinforced by writers such as Baldwin and Gellatly (2006) who note that firms that are aggressive innovators; introducing radically new products that involve patent protection, have higher profits.

The inclusion of patent data in growth models faces a more theoretical challenge through the charge that patents are outputs that should not be included separately in a model alongside inputs such as capital and labour. However, a study by Park and Ginarte (1997) provides strong evidence that patents stimulate the accumulation of both physical and human capital, as well as research and development (R&D). This suggestion of complementarity in production is confirmed in cross-country studies of manufacturing firms that show that larger patent numbers are associated with higher growth and that this effect became stronger in the 1990's compared to the 1980's (Hu and Png, 2010). In this way patents can be seen as an input to the production function by augmenting the productive quality of the machinery and employees of firms as well

as being a direct input to an ongoing cycle of R&D. It is the technical knowledge in the patents that allows for incremental innovation in R&D. Zvi Griliches (1990) recognized this when he concluded that patent data could be used as both an input and output of innovation.

An alternative way of understanding the role of patents is as an index measuring the stock of knowledge available to a country from which inventors draw when looking for new solutions to production dilemmas (Dosi, 1988). For the purpose of this paper I define innovative knowledge as the technical knowledge embodied in a patent. Hence if R&D is an essential input into growth, then patents are instrumental to that process and contribute to growth potential. Empirically we know that firms carrying out R&D are more likely to innovate, to innovate in more original ways, and to use intellectual property (Hanel, 2008). Additionally, firms in high-tech sectors are twice as likely to patent as those in low-tech sectors (Hanel, 2008). Finally, patenting is integral to firms that introduce world first innovations and who export (Hanel, 2008), both key drivers of growth.

3 Review of the Growth Literature

The number of journal articles, working papers, chapters and books on the subject of economic growth is boundless (Durlauf et al. 2005). This section will provide an overview of the literature that focuses on the role that innovation, or technological change, plays in growth. Beginning with the Solow (1956) model, I describe the progression of the effort to make the technology parameter endogenous. This began

with the inclusion of a human capital variable and moved to two-sector models that separated the innovative or highly skilled sector, from the low skilled sector. Following this was an attempt to synthesize the different approaches to account for various stylized facts about growth, including exogenous technological change. The section concludes with a discussion on determinants of growth and endogeneity.

Even before the recent leap forward in innovation, brought about largely by computers, most social scientists agreed that scientific discovery and invention largely explain long-term social changes and economic growth (Schmookler, 1962). Growth theory provides an important vehicle to understanding the role that innovation plays in economic growth. Solow (1956) is recognized as the forefather of all the growth modelling we see today. Whether by direct extension of, or in contrast to the Solow Model, subsequent efforts in growth have built off of the Solow framework. In the growth literature there has been significant effort in recent decades to explicitly model the residual from the Solow model, known as the 'Solow Residual' or total factor productivity (TFP). Alternatively, this can be understood as making the technology parameter endogenous to the model. Important contributions include Romer (1990), Mankiw, Romer and Weil (1994), Grossman and Helpman (1994), Aghion and Howitt (1992), Jones (1995), Barro and Sala-i-Martin (1997), Park and Ginarte (1997), Crosby (2000), Keely (2001) and Bottazzi and Peri (2007). A number of stylized facts (Kaldor, 1957) and key determinants (Barro, 1997 and Durlauf, 2005) for growth have been identified. These form the basis for growth models more generally and endogenous technological growth models specifically.

3.1 The Solow growth model

The Solow (1956) growth model, based on capital and labour inputs, is the canonical model used by economists to explain productivity growth. Using traditional goodness-of-fit measures, the Solow model can be used to explain about forty percent of past growth (Durlauf et al. 2004). To generate growth in output per capita in the Solow model, capital accumulation must proceed faster than the growth rate of the workforce and the depreciation of the existing stock of capital. Alternatively, an increase in the level of capital per worker is needed to produce an increase in the output per worker. The weakness of the Solow model is that the capital to labour ratio converges to a steady state value such that further increases in output per capita must arise exogenously. Hence the sixty percent ‘Solow residual’ or TFP, needed to be studied in order to identify the key determinants of long-run growth.

Despite the Solow residual being criticized as an accounting construct or a catch-all category for omitted variables, the residual continues to be the focus of attention as a measure of the rate of technological change. The inability of neoclassical growth models to explain satisfactorily this part of long-run growth has led to development of a number of models attempting to explain long term-growth by improving our understanding of the factors underlying technological progress.

3.2 Making the technology parameter endogenous in growth models

Romer (1990) presents a neoclassical model with labour and human capital augmenting technological change. In the model technological change provides the incentive for continued capital accumulation and together these two are the determinants

of changes in labour productivity. A key feature of this model is that producers are price setters in a monopolistic competition setting. Mankiw, Romer and Weil (1992) return to the Solow model with decreasing returns to scale, implying perfect competition. They add a third input into the model, human capital. The augmented Solow model and the accompanying empirical results conclude that differences in saving, education and population growth explain most of the variation in growth rates across countries. Moreover, there is evidence that countries with similar technologies, rates of capital accumulation and population growth converge in income per capita. Grossman and Helpman (1994) challenge the findings of the augmented Solow model proposed by Mankiw, Romer and Weil (1992). One of the key assumptions of that paper that they challenge is that all countries have experienced the same level of innovation or technological progress. Moreover, there is an implicit assumption that all countries have a common Cobb-Douglas production function. This assumption raises the issue of parameter heterogeneity discussed in Durlauf et al (2005). By focusing on the most developed countries in the world, I assert the notion that all of these countries are near their steady-state and therefore fixed-effects models are sufficient to address parameter heterogeneity. This is supported by the results from Durlauf et al (2005) where the primary finding is that parameter heterogeneity is strongest for poorer economies.

Grossman and Helpman (1994) consider a two-sector economy separated by their use of skilled versus unskilled labour. They also refer to spillovers, dynamic comparative advantage, cross-country integration and product cycles as key determinants of growth. Romer (1994) provides more support for endogenous growth while recognizing the importance of the Solow model as a giant first step in the

development of formalized growth models. Five basic facts are identified as important evidence not to be ignored in a growth model. These are: (1) there are many firms in a market economy, (2) discoveries differ from other inputs in the sense that many people can use them at the same time, (3) it is possible to replicate physical activities, (4) technological advances come from things that people do, and (5) many individuals and firms have market power and earn monopoly rents and discoveries.

3.3 Synthesis of neoclassical and endogenous growth models

Jones (1995) provides an empirical challenge of the endogenous growth models. According to some endogenous growth models a permanent change in growth rates is possible through permanent changes in variables. Jones' empirical results show that there has not been a permanent increase in growth rates for countries, despite permanent changes in key variables of endogenous growth models, most notably R&D. Barro and Sala-i-Martin (1997) develop a model that combines the treatment of technological progress in endogenous growth models with the convergence of neoclassical models. They separate the world into technologically leading economies and followers. Followers tend to have an excessive incentive to copy and leaders inadequate incentives to innovate.

3.4 Determining the determinants

The basic premise behind the literature presented above is that innovation is the driver of long run growth, whether exogenously or endogenously through improvements in labour (human capital) or capital (R&D, patents). Another key challenge in the

growth literature is determining the appropriate measure of innovation. The determination of variables poses a particular problem for growth due to the fact that growth theories are open-ended, that is, the validity of one theory does not imply that another is invalid (Durlauf et al. 2005). The result is that over 140 variables have been proposed as determinants for growth and all have their merits. To determine which variables to include as control variables one should consider the extreme bounds analysis (EBA), developed in Leamer (1983), as a starting point. EBA involves ensuring that the sign of the variable is constant when considering different specifications of the model. Levine and Renelt (1992) were the first to explore EBA in the context of growth. However, there is a cost to this methodology. Specifically, it may lead to the rejection to variables that do influence growth (Sala-i-Martin, 1997).

3.5 Endogeneity

The concern over which variables to include extends beyond the above discussion. The issue that may be of most importance is endogeneity. Brock and Durlauf (2001) provide an excellent discussion of the issues. The key points are: (1) many of the standard variables in growth models (e.g., openness or trade, rule of law, social capital) are, like growth, the outcomes of socioeconomic linkages and decisions, (2) instruments are often not selected in a manner that overcomes the challenge, (3) instruments are often not uncorrelated with omitted growth determinants and (4) the issues of open-endedness and endogeneity are not exclusive to growth. The challenges put forward are difficult to overcome and this paper attempts to address as many of these as possible. However, the objective of the paper is to determine the suitability of the use

of patent data in growth models and therefore beginning the analysis by assessing against models that have all the trappings above is not inappropriate.

It is clear that there has been much effort to understand and quantify the role that innovation plays in economic growth. Models of varying degrees of complexity have attempted to endogenize different parameters of technological change. In this paper, I will use the framework of one of the simpler models, from Mankiw, Romer and Weil (1994), as the basis of an empirical investigation that will bring some clarity on the usefulness of patent data in growth models. The objective is to determine whether patent families are a good measure of innovation. The following section presents this model.

4 The Model

The theoretical model to be considered here is based on the model of Mankiw, Romer and Weil (1992) which includes a variable to capture improvements in knowledge arising through investments in human capital. In much the same way I will add a variable that captures economically important knowledge. I will focus on knowledge generated by investment in R&D and more specifically the input and output of R&D patents (Griliches, 1990). I start with a traditional Cobb-Douglas production function that includes capital and labour. It is then augmented by the knowledge parameter, denoted as I , raised to the power of $\psi \geq 0$. This ensures increasing returns to scale in the economy; if this were not the case the model is then merely be one of

exogenous technological growth through the Solow residual, or error term in the regressions.

$$Y(t) = K(t)^\alpha L(t)^{1-\alpha} I(t)^\psi. \quad (1)$$

Dividing both sides through by L gives the following expression labour productivity

$$y(t) = k(t)^\alpha i(t)^\psi. \quad (2)$$

Savings is exogenous in our model and I assume that the amount saved is invested in both capital and knowledge. The capital accumulation equation is similar to Mankiw, Romer and Weil (1992), with exception that the exogenous technological growth parameter is omitted. The term, s_k is the share of income invested in tangible assets

$$\dot{k}(t) = s_k y(t) - (n + \delta)k(t). \quad (3)$$

The knowledge accumulation equation is

$$\dot{i}(t) = s_i y(t) - \lambda i(t). \quad (4)$$

The term, s_i is the share of income invested in knowledge accumulation and the last term represents those ideas that eventually become obsolete. The term λ can be seen as the depreciation of knowledge. This reflects those patents that have either expired or been abandoned.

On a balanced growth path $\dot{k}(t) = 0$ and $\dot{i}(t) = 0$, therefore

$$s_k y(t) - (n + \delta)k(t) = 0 \quad (5)$$

and

$$s_i y(t) - \lambda i(t) = 0. \quad (6)$$

Substitute equation (2) into equation (5) and solve for $i(t)$

$$i(t) = \left(\frac{n + \delta}{s_k} \right)^{\frac{1}{\psi}} k(t)^{\frac{1-\alpha}{\psi}}. \quad (7)$$

Now substituting (7) into (6) and using (2) gives

$$s_i = \lambda \left(\frac{n + \delta}{s_k} \right)^{\frac{1-\psi}{\psi}} k(t)^{\frac{1-\alpha-\psi}{\psi}}. \quad (8)$$

Solving for $k(t)$ gives

$$k^*(t) = \left[\left(\frac{s_i}{\lambda} \right) \left(\frac{s_k}{n + \delta} \right)^{\left(\frac{1-\psi}{\psi} \right)} \right]^{\left(\frac{\psi}{1-\alpha-\psi} \right)}. \quad (9)$$

Substituting (9) into (6) gives an expression for $i^*(t)$

$$i^*(t) = \left[\left(\frac{s_i}{\lambda} \right)^{\left(\frac{1-\alpha}{\alpha} \right)} \left(\frac{s_k}{n + \delta} \right)^{\left(\frac{\alpha}{1-\alpha-\psi} \right)} \right]. \quad (10)$$

Now substitute (9) and (10) into (2) to get

$$y(t) = \left[\left(\frac{s_i}{\lambda} \right)^{\left(\frac{1}{\alpha} \right)} \left(\frac{s_k}{n + \delta} \right)^{\left(\frac{1}{\psi} \right)} \right]^{\eta}, \quad (11)$$

where

$$\eta = \left(\frac{\alpha\psi}{1-\alpha-\psi} \right). \quad (12)$$

Now, to express the production function in terms of $i(t)$, $k(t)$, n and δ . To do this solve equation (6) for s_i and use equation (2)

$$s_i = \lambda \frac{i(t)^{1-\psi}}{k(t)^{\alpha}}. \quad (13)$$

Now substituting (9) into (13) and solve for s_i

$$s_i = \lambda \left(\frac{i(t)^{\left(\frac{1-\psi}{1+\eta}\right)}}{\left(\frac{s_k}{n+\delta}\right)^{\left(\frac{1-\psi}{\psi}\right)\left(\frac{\eta}{1+\eta}\right)}} \right). \quad (14)$$

Now, using this in equation (11) gives

$$y(t) = i(t)^{\left(\frac{1-\psi}{\alpha}\right)\left(\frac{\eta}{1+\eta}\right)} \left(\frac{s_k}{n+\delta}\right)^{\eta \left(\frac{(1+\eta)\alpha - (1-\psi)\eta}{\alpha\psi(1+\eta)}\right)}. \quad (15)$$

Using (12) and some algebraic manipulation allows for simplification to

$$y(t) = i(t)^{\left(\frac{\psi}{1-\alpha}\right)} \left(\frac{s_k}{n+\delta}\right)^{\left(\frac{\alpha}{1-\alpha}\right)}. \quad (16)$$

Taking the natural log of (16) yields

$$\ln y(t) = \left(\frac{\psi}{1-\alpha}\right) \ln i(t) + \left(\frac{\alpha}{1-\alpha}\right) \ln s_k - \left(\frac{\alpha}{1-\alpha}\right) \ln(n+\delta). \quad (17)$$

Equation (17) allows us to use; population growth for n , patenting for $i(t)$ and the share of GDP that is investment to proxy s_k . This follows the Mankiw, Romer and Weil (1992) model closely. The consideration of other determinants and dynamic relationships requires a more general framework. For this I follow the generic representation put forward by Durlauf et al. (2004); $\gamma = \psi X + \pi Z + \varepsilon$. Where γ is labour productivity, X represents the Solow growth determinants capital and labour and Z are the growth determinants that are not in Solow's theory. In this paper it includes patenting and other determinants that should be controlled for to make the results as robust as possible. Since I am interested in dynamic panel data estimation, techniques are required for non-stationary heterogeneous panel.

5 Data and Methodology

This section describes the sources of the data and the transformations made with the data. I begin with a list of the sources of data and countries considered. A brief overview of patent families follows. A paragraph on the importance of business cycles is next, followed by a presentation of the formulas of the data transformations. The section concludes with discussions on endogeneity and dynamic modelling, or co-integration.

5.1 The data set

The data used in estimation include variables over the time period 1991 to 2007. To measure productivity I used both output per unit of labour and output per hour worked. For users only interested in OECD countries it is recommended by PWT to use the hours-worked series. Human capital data comes from the Barro and Lee (1994) and can be found at <http://www.barrolee.com/data/dataexp.htm>. The patent data was downloaded from the World Intellectual Property Organization website <http://www.wipo.int/ipstats/en/resources/> (WIPO, 2010) on September 15th, 2010. The 26 countries included in the empirical analysis include; Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The countries were selected based on the data availability for the key variables of interest.

5.2 Patent families

One of the main challenges in using patent data as a measure for innovation is that total counts of patents results in multiple counts for those inventions that are filed in multiple countries. Additionally, it is possible that administrative differences may result in an invention having multiple patents associated with it in one country, while at the same time requiring fewer or even one patent in another country. Hence, I use patent families in order to more accurately measure the rate of innovation in a country. The recently published *OECD Patent Statistics Manual* defines patent families as “the set of patents (or applications) which are related to each other by one or several common priority filings” (OECD, 2009). A priority filing is the first patent filing made to protect an invention and most often is made in the country of residence of the applicant (OECD, 2010). The first effort to construct patent families dates back to the 1940s (OECD, 2010). Recent efforts include both the OECD (OECD, 2009) and WIPO (WIPO, 2010). This paper considers the WIPO effort. I consider two measures of families: the first is the traditional patent family that includes all patents that are related⁷ and the second is a sub-set of the first and must include a filing in at least two jurisdictions.

5.3 Business cycles

One key factor that must be addressed in growth models is business cycles. The reason for this is that business cycles can drive changes in variables that may result in correlation that may be confused with causality. Given that our model considers over 15

⁷ Note that the first measure does not meet the OECD definition of a patent family provided above. A 2010 OECD report, *Insight into different types of patent families*, provides an excellent overview of patent families and how they are constructed.

years of data this is important. Studies such as Mankiw, Romer and Weil (1992) and Barro (1997) used measures of change over five year intervals. This was done to account for business cycles, but was also reflective of data limitations. For example the human capital data from Barro and Lee (1994) was only measured every five years. I take a different approach. I average all variables (both dependent and independent) over k years (3 to 7). This creates an observation for each year that is the average over k years from year $t-k$ to year t , essentially this is a moving average (MA) of all variables of interest. This allows me to include many more observations in the model.

One challenge occurs when I consider the human capital data. The Barro and Lee (1994) human capital data is measured in five-year intervals. To obtain my values I consider the averages from 5 and 7 years. This ensures that there is some change in the variable over time. The weakness is that I am assuming a smooth, or linear, transition during the five-year period between observations. Given that the Barro and Lee (1994) data is seen to be the best sources for human capital data, I accept this trade-off.

5.4 Definitions of variables used

Note that all variables are in natural logs. When differencing I will denote this as $D(\text{variable name})$ and when taking lags for instrumentation purposes I will denote this as $L\#(\text{variable name})$, where $\#$ is the number of lags.

Labour Productivity

$$\ln(rgnpl(h)_{t,s}) = \frac{\sum_{i=0}^{s-1} \ln(rgnpl(h)_{t-i})}{s} : \text{Purchasing power parity (PPP) Converted GNP}$$

Laspeyres per hour worked by employees at 2005 constant prices

$$\ln(rgdpl_{t,s}) = \frac{\sum_{i=0}^{s-1} \ln(rgdpl_{t-i})}{s} : \text{PPP Converted GDP Laspeyres per capita at 2005 constant prices}$$

Population Growth

$$\ln(n_{t,s}) = \ln\left(\frac{\text{population}_t - \text{population}_{t-s}}{\text{population}_{t-s}}\right) : \text{Change in population}$$

Investment

$$\ln(ri_{t,s}) = \frac{\sum_{i=0}^{s-1} \ln(ri_{t-i})}{s} : \text{Investment share of GDP at 2005 constant prices and PPP converted}$$

Foreign Oriented Patent Families

$$\ln(fopf_{t,s}) = \ln\left(\frac{\sum_{i=0}^{s-1} fopf_{t-i}}{s}\right) : \text{Foreign Oriented Patent Families by country of origin}$$

$$\ln(lfopfpc_{t,s}) = \ln\left(\frac{\sum_{i=0}^{s-1} \frac{fopf_{t-i}}{n}}{s}\right) : \text{Foreign Oriented Patent Families per capita by country of origin}$$

origin

Government

$$\ln(rg_{t,s}) = \frac{\sum_{i=0}^{s-1} \ln(rg_{t-i})}{s} : \text{Government share of GDP at 2005 constant prices and PPP converted}$$

Openness

$$\ln(ro_{t,s}) = \frac{\sum_{i=0}^{s-1} \ln(ro_{t-i})}{s} : \text{Imports plus Exports as a share of GDP at 2005 constant prices}$$

and PPP converted

Human Capital

$$\ln(hc_{t,s}) = \frac{\sum_{i=0}^{s-1} \ln(hc_{t-i})}{s} : \text{5 year MA of Average years of total schooling attained by the}$$

population over 15 years of age, measured in five year intervals

5.5 Summary of descriptive statistics

Table II-1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	IPSHIN P-values H ₀ : Series is non-stationary
Labour productivity (rgnpl)	468	28155.91	9870.8	5335.793	68192.2	1.000
Labour productivity per hour (rgnpl(h))	468	35.4444	12.2041	8.10998	67.43501	0.990
Population	468	36060.43	57125.51	254.719	301580	1.000
Investment as a share of GDP (ri)	468	22.2595	3.9489	13.13365	42.29683	0.200
Human capital 5-year MA (hc)	432	2.2313	0.1907	1.539272	2.551677	0.812
Foreign oriented patent families (fopf)	468	6301.015	14034.06	3	68701	0.832
Patents (p)	338	41202.96	105615.1	16	529593	0.996
Patent Families (pf)	160	33765.49	69356.27	459	302892	0.928
Foreign oriented patent families – 2011 data (fopfb)	160	9732.125	16501.98	118	64789	0.150
Government as a share of GDP (rg)	468	9.1865	2.5402	4.49974	16.52692	0.010
Openness – total trade as a share of GDP	468	71.4210	46.9639	16.09933	319.1829	1.000

The summary statistics show that non-stationarity exists in all of the variables except for our measure of size of government. To test for stationarity I employ the t-test developed by Im, et al., (2003) for unit roots in heterogeneous panels. The test is constructed from the mean of the individual Dickey-Fuller t-statistics of each unit in the panel. The test assumes that all series are non-stationary under the null hypothesis. I use a single lag of the dependent variable to allow for serial correlation in the errors. A simple t-test is consistent under the alternative that only a fraction of the series is stationary. We find that the Solow determinants are all non-stationary up to three lags. Furthermore, all of the innovation measures, i.e., human capital and the various patenting measures are non-stationary. Finally, the level of openness is non-stationary and the measure of government is stationary.

6 Results

This section reports the empirical results of the tests of the new measure of innovation. I begin by replicating the early set of growth models described above for my sample (Solow and Mankiw, Romer and Weil) and use these results as the base case against an assessment of whether the use of the more precise measures of innovation can improve performance. After finding that the preliminary panel data analysis does suggest that the inclusion of successively more precise patenting measures does improve performance, a series of robustness tests are undertaken to assess whether the assumptions implicit in this interpretation are justified. Here the important questions concern the issues of heteroskedasticity, endogeneity, stationarity, serial correlation and

cross sectional correlation. To do so I test a set of complementary models that control for the presence of heteroskedasticity, endogeneity and cross sectional correlation. I then consider more dynamic models that relax the assumptions of endogeneity, stationarity, serial correlation. The section concludes with an overview of these results.

6.1 The base model

The starting point for this analysis is a simple panel model with 26 countries covering 18 years, from 1991 to 2007. The data is not balanced as some observations are missing and the patenting data is limited, resulting in some variation in the number of observations. I begin the analysis by estimating the traditional Solow model. I use real output per hour as labour productivity and real investment as a share of GDP and population growth as my Solow determinants. I estimate these variables in models that include a moving-average (MA) from 3 to 7 years. I employ a fixed-effects (FE) model, with year dummies, as I am interested in analyzing variables that change over time. The FE model controls for all time-invariant differences between the countries (Wooldridge 2002). Despite the set of countries being fairly homogeneous, in that the sample is comprised of a sub-set of OECD countries, it is important that differences in culture attitudes, government structures, and geographical locations are accounted for. Although some countries may share some of these characteristics, the mix is unique for each. I explore the relaxing of this assumption below.

I begin by looking at the Solow model. I take the 3 to 7 year moving averages of labour productivity, investment as a share of GDP and population change. Table II-2 presents the Solow model results. All of the specifications perform well with the within

R^2 greater than 0.8 for each one. The higher R^2 are found on the 6 and 7 year MA models, with value of 0.862 and 0.872 respectively compared to 0.828, 0.838 and 0.820 for the 3, 4 and 5 year MA models. Additionally, although not as important in an FE model, the between and overall R^2 are both highest in the 5 year model. The between R^2 is 0.150, compared to 0.104, 0.086, 0.088 and 0.058 for the 3, 4, 6 and 7 year MA models, respectively. Investment is significant in all the MA specifications, while population change is significant in the 3, 5 and 6 year MA specifications. Overall, it seems that the longer period averaging, that is 5 to 7 years, provides more explanatory power in the case of the Solow model. When compared to the empirical results from the Mankiw, Romer and Weil (1992) that look at Solow model I find that, when considering the 5-year MA model, my measure of investment returns a similar result to theirs when they consider only OECD countries, 0.366 in my model and 0.392 in their model. However, the impact of population change is much different, with my model having an estimate of -0.018, compared to a much larger -0.753 in their model. This is likely due to the different rates of population growth between the two sample periods, 1960-1985 for the MRW paper and 1991-2007 for my paper.

Table II-2 The Solow Model

All models XTREG FE with year dummies	Solow	Solow	Solow	Solow	Solow
	3 - year average of variables	4 - year average of variables	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.010* (0.005)	-0.005 (0.007)	-0.018*** (0.005)	-0.010* (0.006)	-0.010 (0.007)
Investment	0.109*** (0.032)	0.096*** (0.035)	0.366*** (0.114)	0.093** (0.042)	0.082* (0.047)
Constant	2.95*** (0.111)	3.00*** (0.122)	2.43*** (0.371)	3.32*** (0.147)	3.35*** (0.166)
R ² – Within	0.828	0.838	0.819	0.862	0.872
R ² – Between	0.104	0.086	0.150	0.088	0.058
R ² – Overall	0.073	0.071	0.089	0.077	0.078
Rho (variance due to u _i)	0.985	0.986	0.984	0.988	0.989
Observations	468	468	471	470	470

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

Next I look at the Mankiw, Romer and Weil (MRW) (1992) model. This is a model where innovation occurs through human capital. The MRW model includes the same variables as the Solow model with the addition of a measure of human capital, the number years of total schooling attained by the population over 15 years of age. This is from the Barro and Lee (1994) and is measured in 5-year intervals. Therefore I only estimate MA models with 5 to 7 years. Additionally, as the human capital variable I(2), I take the first-difference to make it consistent with the other variable of interest, that is I(1). Note that a test of stationarity of the first-difference fails to reject the null of non-stationarity in the Im, et al., (2003) test. Table II-3 shows that the 5-year model is the only one where all the variables of interest are significant. Again, this is despite the fact that the 5 year model has the lowest within R², with a value of 0.855, compared to 0.864 and 0.874 for the 6 and 7 year models respectively. However, the difference between 0.863 for the 5 year model and 0.879 for the 7 year model is not seen to be enough to reject the 5 year model. The relative goodness of fit Akaike Information Criterion (AIC)

statistic, which is based on the log-likelihood of the model, reveals that the MRW model is a better fit, with an AIC of -1440.31 compared to -1395.22 for the Solow model. In conclusion all the specifications models work fairly well, but it is the 5 year MA model that also confirms the findings of the MRW model.

Table II-3 Mankiw, Romer & Weil Model (Solow + Human Capital)

All models XTREG FE with year dummies	MRW	MRW	MRW
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.011** (0.005)	-0.008* (0.006)	-0.006 (0.005)
Investment	0.074* (0.038)	0.049 (0.039)	0.023 (0.040)
D(Human Capital)	0.637** (0.281)	0.764** (0.349)	0.691** (0.341)
Constant	3.42*** (0.129)	3.52*** (0.132)	3.60*** (0.135)
R ² – Within	0.855	0.864	0.874
R ² – Between	0.001	0.001	0.000
R ² – Overall	0.091	0.091	0.090
Rho (variance due to u _i)	0.982	0.983	0.986
Observations	426	427	428

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

I now want to consider the difference made by patents as a measure of innovative activity not captured by physical or human capital accumulation. Patents are additional inputs to research, final process improvements and new products. If this is true the predictive power of the Solow and MRW models should be improved by adding patenting activity to the model. The first patent measure used to measure innovation is the number of worldwide patent filings from each country. Table II-4 shows that when a simple patent count is used, the equation fit of the model falls rather than rises and all three MA specifications of the Solow variables lose significance. The within R² is

considerably lower for each specification of the model. For example, in the 5 year MA model it drops from 0.855 in the MRW model to 0.791. It is clear that while patents have some explanatory power, there is a confounding effect on the traditional determinants of growth. This could be attributed to the fact that patent data is fraught with issues that lead to systemic errors in interpretation, that include both over and under estimations of innovative activity depending on sector or firm type (Kleinknecht et al., 2002). This, along with questions as to whether patents are a measure of inputs or outputs, are the primary reasons why patenting has not become a standard determinant within growth models, despite their appeal as a measure for technological change.

Table II-4 MRW with Patents

All models XTREG FE with year dummies	MRW + Patents	MRW + Patents	MRW + Patents
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.009 (0.008)	-0.002 (0.008)	-0.009 (0.009)
Investment	0.047 (0.046)	0.040 (0.056)	0.052 (0.062)
D(Human Capital)	0.683** (0.281)	0.934*** (0.263)	0.866 (0.266)
Patents	0.084*** (0.014)	0.090*** (0.030)	0.085*** (0.031)
Constant	2.75*** (0.176)	2.74*** (0.288)	2.71*** (0.304)
R ² – Within	0.791	0.797	0.804
R ² – Between	0.187	0.186	0.188
R ² – Overall	0.223	0.217	0.210
Rho (variance due to u _i)	0.987	0.990	0.992
Observations	258	235	212

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

As discussed previously one of the drawbacks of the traditional measure of international patenting is the presence of double counting. That is, an invention that is patented in more than one country will be counted once for each country it is patented in. This is problematic. To account for this, I next consider another measure of international patenting that uses the concept of patent families. This treatment of patent data eliminates double counting as it relates to all patents that are linked to a single priority, or initial, patent application. Again building on the MRW model, I replace the previous patenting measure with the measure of patent families. Table II-5 shows that the use of patent families provides an improvement to the fit of the model for all of the MA specifications. The within R^2 is higher for each specification of the model, this despite a much smaller sample size than the previous model. Specifically the 5 year MA model for patent families has a 0.832 within R^2 , compared to 0.792 for the model with traditional patent counts. However, AIC statistics reveal that the first model is a better fit, with an AIC of -1033.03 compared to -556.19 for the model that includes patent families. This can largely be attributed to the fact that there are almost three times as many observations in the model with traditional patents. When I restrict the first model to the same number of observations as the patent family model, I find that the within R^2 falls to 0.609 and the AIC statistic is -522.42, resulting a worse fit than a model with patent families. I conclude here that patent families are a preferred measure of innovation compared to the use of a simple patent count.

Table II-5 MRW with Patent Families

All models XTREG FE with year dummies	MRW + Patents Families	MRW + Patents Families	MRW + Patents Families
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.004 (0.007)	-0.005 (0.005)	-0.001 (0.015)
Investment	-0.005 (0.050)	0.022 (0.065)	0.042 (0.090)
D(Human Capital)	0.562** (0.228)	0.832*** (0.264)	0.459 (0.316)
Patent Families	0.072*** (0.023)	0.071** (0.035)	0.074 (0.047)
Constant	3.12*** (0.409)	3.04*** (0.417)	2.95*** (0.569)
R ² – Within	0.832	0.825	0.773
R ² – Between	0.105	0.107	0.122
R ² – Overall	0.096	0.106	0.128
Rho (variance due to u _i)	0.998	0.999	0.999
Observations	91	73	54

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

I now introduce the key variable of interest of this paper. Foreign oriented patent families are similar to patent families in that all members of the family are linked to a single priority filing. The difference is that at least one member of the family must be a filing in a foreign jurisdiction. The idea behind this suggestion is that patents filed internationally are likely to be those that have highest economic value and therefore may better measure of what is meant by innovation. The ideas embodied in them are more likely to result in products and process improvements and follow-on incremental innovations. I replace the earlier measure of patent families with this narrower measure.

Table II-6 shows that when I compare the use of foreign oriented patent families to the previous two measures of innovation the regression results improve considerably. Comparison with Tables II-4 and II-5 indicates that this specification has higher within, between and overall R² for all three MA specifications. Specifically, the average R² for

the model including foreign oriented patent families is 0.869 for within, 0.246 for between and 0.298 for overall. When I compare this with the average R^2 for the model that includes patent families (0.811 for within, 0.111 for between and 0.110 for overall) and for the model that included traditional patent count (0.797 for within, 0.187 for between and 0.217 for overall), I conclude that foreign oriented patent families improve the fit of the model. Furthermore, an F-test between 5 year MA specification of the foreign oriented patent family model (unrestricted) and the 5 year MA specification of the MRW model (restricted) results in an F statistic value of 16.956, and a rejection of the null hypothesis, at the 1% level, that the foreign oriented patent family has no partial effect on the labour productivity. That is, there is an effect on labour productivity by innovation as measured by foreign oriented patent families. The AIC statistics also confirms that foreign oriented patent families are the preferred measure of innovation. The AIC for the preferred measure is -1057.07, compared to -1033.03 for traditional patent counts, when the two models are constrained to the same number of observations. To provide additional comparison of the three measures of patents I perform the following exercise. I use a likelihood ratio test to compare each model with a patent variable (unrestricted) to the MRW model (restricted). I obtain the following Chi-square statistics; 65.19 for foreign oriented patent families, 12.52 for patent families and 41.15 for traditional patent. Each model rejects the null that the respective patenting variable does not add significant explanatory power to the model. When I compare the three Chi-square values I conclude that foreign oriented patent families are the best of the three variables. Therefore, I conclude that this is an important measure of growth in labour productivity.

This specification has additional appeal because the Solow and human capital determinants are significant in all three specifications. Although not central to the hypothesis put forward in this paper, that is that foreign oriented patent families are indeed a good proxy for innovation, the argument holds more weight if the findings of the efforts of Solow (1956) and Mankiw, Romer and Weil (1992) are present. This is important in order to place this paper amongst the broader growth literature.

Table II-6 MRW with Foreign Oriented Patent Families

All models XTREG FE with year dummies	MRW + FOPF (2010)	MRW + FOPF (2010)	MRW + FOPF (2010)
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.018** (0.007)	-0.016** (0.007)	-0.019** (0.008)
Investment	0.133*** (0.034)	0.131*** (0.036)	0.136*** (0.038)
D(Human Capital)	0.641** (0.257)	0.864** (0.342)	0.821*** (0.306)
Foreign Oriented Patent Families	0.062*** (0.014)	0.064*** (0.014)	0.064*** (0.014)
Constant	2.75*** (0.180)	2.56*** (0.177)	2.70*** (0.200)
R ² – Within	0.867	0.869	0.872
R ² – Between	0.249	0.247	0.243
R ² – Overall	0.306	0.300	0.289
Rho (variance due to u _i)	0.982	0.984	0.987
Observations	378	355	332

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

More recent analysis suggests the importance of two other variables not included in the MRW model as determinants of growth in advanced economies: openness to trade, and government size (Barro and Martin, 2004; Durlauf, et al., 2005). The work of Barro & Martin (2002) shows that the size of government, as measured by total government expenditures as a share of GDP, is expected to have a negative impact on growth and openness, as measured by imports plus exports as a share of GDP and is

expected to have a positive impact on growth. To again show how the movement to greater precision in measuring innovation improves productivity models, I again add the initial patent measure to the enhanced MRW model. Table II-7 shows that a simple patent count is significant in this specification. Similar to the simple patenting models in Table II-4, the usual Solow determinants lose their significance. However, the government and openness variables are significant, and take on the expected signs. Also, the within, between and overall R^2 for all three MA specifications are higher when compared to the narrower model above, with 5 year MA within R^2 for the full model being 0.812 compared to 0.791 for the MRW model with patents. Moreover, the AIC is lower at -1055.85 compared to -1033.03. This suggests that these two additional explanatory variables are important.

Table II-7 Full Model with Patents

All models XTREG FE with year dummies	Full + Patents	Full + Patents	Full + Patents
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.004 (0.008)	0.006 (0.008)	-0.003* (0.011)
Investment	0.033 (0.053)	0.032 (0.060)	0.061 (0.069)
D(Human Capital)	0.564* (0.260)	0.794** (0.336)	0.681* (0.357)
Government	-0.264** (0.110)	-0.279** (0.124)	-0.253* (0.141)
Openness	0.179** (0.075)	0.197** (0.0856)	0.208** (0.093)
Patents	0.079*** (0.025)	0.084*** (0.026)	0.076*** (0.027)
Constant	2.66*** (0.622)	2.61*** (0.677)	2.44*** (0.756)
R^2 – Within	0.812	0.819	0.824
R^2 – Between	0.299	0.298	0.331
R^2 – Overall	0.320	0.316	0.342
Rho (variance due to u_i)	0.987	0.989	0.991
Observations	258	235	212

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

I then add these two determinants to the model that included the second patent measure, patent families. Table II-8 reports these results. The first important finding is that the overall explanatory power of the equations improves with the use of patent families over patents when I restrict the latter to same number of observations. The AIC statistic for the model with the traditional patenting variable is -522.44; while for the patent family model it is -572.86. Again the models are constrained to the same number of observations for comparison. However, the patent family variable is not significant in this specification. Furthermore, the Solow determinants and openness are not significant in all three MA specifications. The government variable loses its significance in the 7 year MA model and human capital loses its significance in both the 6 year and 7 year MA model. This is contrasted by the 5 year and 6 year MA models having higher within R^2 than the previous model, 0.866 and 0.843 compared to 0.832 and 0.825. Despite the increases in R^2 this specification offers little explanation for growth.

Table II-8 Full Model with Patent Families

All models XTREG FE with year dummies	Full + Patents Families	Full + Patents Families	Full + Patents Families
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	0.003 (0.009)	-0.001 (0.005)	-0.010 (0.007)
Investment	-0.037 (0.065)	-0.014 (0.080)	-0.002 (0.107)
D(Human Capital)	0.342* (0.193)	0.380 (0.275)	0.071 (0.341)
Government	-0.388*** (0.136)	-0.334** (0.158)	-0.330 (0.215)
Openness	0.087 (0.115)	0.006 (0.132)	-0.080 (0.174)
Patent Families	0.044 (0.027)	0.055 (0.033)	0.058 (0.049)
Constant	3.98*** (0.696)	4.01*** (0.795)	4.24*** (0.998)
R ² – Within	0.866	0.843	0.798
R ² – Between	0.296	0.273	0.205
R ² – Overall	0.260	0.254	0.204
Rho (variance due to u _i)	0.999	0.999	0.999
Observations	91	73	55

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

I now introduce the foreign oriented patent family into the larger model. Table II-9 shows the results. I find that the full model with foreign oriented patent families is preferred to all other specification. The foreign oriented patent family model has higher within, between and overall R² for all three MA specifications when compared to the other measures of patenting. Specifically, the 5 year MA specification with foreign oriented patent families yields a within R² of 0.881, compared to 0.866 and 0.812 for the models that include patent families and traditional patents, respectively. The AIC statistics are -1083.99 and -1055.85 for the models that include foreign oriented patent families and traditional patents, respectively, when constrained to the same number of observations. An F-test between 5 year MA specification of the full model with the

foreign oriented patent family variable (unrestricted) and the 5 year MA specification of the full model excluding the foreign oriented patent variable (restricted) results in an F-test value of 33.199. This means that a rejection of the null hypothesis that the model that includes foreign oriented patent families does not provide a statistically significant better fit than the a model without this measure. When the unrestricted and restricted models are constrained to the same number of observations, the AIC statistics are -1431.35 and -1370.57, respectively. To provide additional comparison of the three measures of patents I revisit the use of the likelihood ratio test to compare each model with a patent variable (unrestricted) to the full model (restricted). I obtain the following Chi-square statistics; 17.19 for foreign oriented patent families, 5.19 for patent families and 2.66 for traditional patent. The two patent family models reject the null hypothesis that the respective patenting variable does not add significant explanatory power to the model. However, with respect to the model with the traditional patent measure I do not reject the null hypothesis and therefore conclude that the model is not improved with the inclusion of the patenting variable. When I compare the three Chi-square values I conclude that foreign oriented patent families are the best of the three variables. I again confirm that foreign oriented patent families are a good proxy for the type of innovation that leads to growth in labour productivity. Again, the result is that the Solow determinants regain their significance in all three specifications. In fact, all of the variables interest are significant and take on the appropriate signs. Again, this is not the objective of this paper, but if variables were significant and had signs that were counter to stylized facts or previous results, there would be cause for concern.

Table II-9 Full Model with Foreign Oriented Patent Families

All models XTREG FE with year dummies	Full + FOPF (2010)	Full + FOPF (2010)	Full + FOPF (2010)
	5 - year average of variables	6 - year average of variables	7 - year average of variables
Population change	-0.015** (0.006)	-0.012** (0.007)	-0.017** (0.007)
Investment	0.124*** (0.038)	0.125*** (0.041)	0.147*** (0.045)
D(Human Capital)	0.691*** (0.247)	1.039*** (0.340)	0.914*** (0.296)
Government	-0.177*** (0.062)	-0.171** (0.067)	-0.142** (0.070)
Openness	0.199*** (0.057)	0.205*** (0.060)	0.209*** (0.063)
Foreign Oriented Patent Families	0.057*** (0.013)	0.059*** (0.014)	0.059*** (0.014)
Constant	2.35*** (0.379)	2.20*** (0.382)	2.13*** (0.426)
R ² – Within	0.881	0.883	0.884
R ² – Between	0.436	0.450	0.481
R ² – Overall	0.443	0.454	0.4789
Rho (variance due to u _i)	0.981	0.983	0.985
Observations	378	355	332

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

Note that there has been an updated version of the foreign oriented patent family data. These are not presented in the text because there are fewer observations available, nine years versus eighteen years for the 2010 data series. Once I consider the moving averages, the ratio of observations available drop from two-to-one to three-to-one. Table II-15 in Appendix 8.1 provides the results for the use of this data series. As expected the 2010 data release performs somewhat better than the 2011 data. However even here, the 2011 foreign oriented patent family data performs better than either patents or patent families as a determinant of productivity growth.

6.2 Treating heteroskedasticity

I have shown that foreign oriented patent families are an important variable for measuring innovative inputs. However, these results come with many caveats. Going forward I will relax these assumptions and determine whether the initial findings hold. I now focus solely on the 5 year MA specification. There are two reasons for this. First, in the above exercises the 5 year models perform as well or better than the alternatives and for the Solow and MRW models are consistent with previous empirical efforts. Second, my treatment of the human capital variable, which requires an averaging of measurements taken every five years and is best interpreted in a 5 year MA model. The first concern with the above models is heteroskedasticity. To generate robust standard errors I use the sandwich estimation procedure for estimating the covariance matrix of parameter estimates that gives asymptotically consistent covariance matrix estimates without making distributional assumptions and allowing for the possibility that the assumed model is incorrect (Huber, 1967). With this I revisit the 5 year MA model for the Solow specification, the MRW specification, the MRW plus three different measures of patenting and finally the full model with foreign oriented patent families. Table II-10 reports the results. The outcome of this is that many of the variables are no longer significant in many of the specifications. With respect to the Solow model, only investment is significant. In the MRW model only human capital is significant. When I add in the various measures for patenting, it is only foreign oriented patent families that are significant. It is interesting to note that in the specifications where patents are not significant, the human capital variable is and where patents are, human capital is not. I raise this as both are serving as proxies for innovation. In the full specification foreign

oriented patent families and investment are both significant. The models that include foreign oriented patent families have the highest within, between and overall R^2 . My variable of interest passes the first test for robustness.

Table II-10 Robust Standard Error Models

All models XTREG FE with year dummies and robust standard errors	Solow	MRW	MRW + Patents	MRW + Patent Families	MRW + FOPF	Full + FOPF
Population change	-0.018 (0.015)	-0.011 (0.014)	-0.009 (0.016)	-0.003 (0.012)	-0.018 (0.020)	-0.015 (0.018)
Investment	0.366* (0.182)	0.056 (0.062)	0.047 (0.095)	-0.005 (0.075)	0.134** (0.060)	0.124* (0.071)
D(Human Capital)		0.566* (0.294)	0.683** (0.285)	0.562*** (0.189)	0.641 (0.425)	0.691 (0.476)
Government						-0.177 (0.164)
Openness						0.199 (0.144)
Patents			0.084 (0.069)	0.072 (0.048)	0.061* (0.032)	0.057* (0.030)
Constant	2.43*** (0.602)	3.48*** (0.228)	2.75*** (0.638)	3.12*** (0.615)	2.74*** (0.401)	2.35** (0.920)
R^2 - Within	0.819	0.863	0.791	0.832	0.867	0.881
R^2 - Between	0.150	0.001	0.187	0.105	0.250	0.436
R^2 - Overall	0.089	0.098	0.223	0.096	0.306	0.443
Rho (variance due to u_i)	0.984	0.981	0.987	0.998	0.982	0.981
Observations	471	448	258	91	378	378

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

6.3 Relaxing the assumptions on serial and cross sectional dependence

The previous section confirms that the foreign oriented patent family variable is the preferred proxy measure of innovative inputs. Another important assumption made in the base models was that there was no serial or cross sectional dependence. To address this I employ the panel corrected standard errors technique to address these issues. This includes a panel specific AR1 process and an assumption of heteroskedasticity within the panels. Cross sectional dependence is also assumed to be present. The results are presented in Table II-11. The Solow model only has investment

as significant and the MRW model has none of the variables as significant. When I add the various measures of patents the result is that both patents and foreign oriented patent families are significant in their respective specification, along with population change. Investment and human capital are not significant in these specifications. At the same time, in the model that includes the patent family variable, I find that patenting and population change are not significant, while both investment and human capital are. The full model shows that investment, openness and foreign oriented patent families are significant. Again my measure for innovation, foreign oriented patent families, stands the test of robustness.

Table II-11 Correcting for Serial and Contemporaneous Correlation

All models XTPCSE – Panel Specific AR process and heteroskedasticity	Solow	MRW	MRW + Patents	MRW + Patent Families	MRW + FOPF	Full + FOPF
Population change	0.019 (0.015)	-0.008 (0.005)	-0.017*** (0.006)	-0.003 (0.008)	-0.008** (0.004)	-0.005 (0.004)
Investment	0.780*** (0.155)	0.010 (0.038)	0.064 (0.051)	-0.582*** (0.067)	0.047 (0.032)	0.092*** (0.034)
D(Human Capital)		0.108 (0.145)	-0.044 (0.223)	0.538** (0.251)	0.052 (0.133)	0.071 (0.082)
Government						-0.022 (0.039)
Openness						0.217*** (0.023)
Patents			0.060*** (0.006)	-0.008 (0.006)	0.050*** (0.007)	0.041*** (0.005)
Constant	1.45*** (0.227)	3.71*** (0.124)	dropped	dropped	dropped	2.26*** (0.238)
R ² - Within	0.992	0.999	0.999	0.999	0.999	0.998
Rho (variance due to u _i)	0.753	0.851	0.797	0.994	0.786	0.910
Observations	471	579	258	91	378	378

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

6.4 Endogeneity

One of the most challenging issues in growth econometrics is endogeneity. When considering endogeneity there are a number of issues to consider. The first is the statistical sense of endogeneity, that the independent variables are correlated with the error term. The second is when there are two or more variables that are jointly determined in the model. The third is measurement errors in the independent variables. The fourth, and perhaps most challenging, is the omitted-variable bias. There are a number of tests to help determine the suitability of the instruments selected. Durlauf et al. (2005) provides a list of 145 variables that could be considered in growth models and numerous options for instruments for each. The most common instrument is the lag or initial value of the variable in question. I employ a number of different instrumental variables (IV) techniques. A Hausman test that compares models that includes labour productivity as the dependent and lagged labour productivity as an independent with the same model and investment yields a Chi-squared statistic of 6.94. This means that I do not reject the null hypothesis and find that investment is exogenous. Alternatively, this can be understood as savings being exogenous and savings being equal to investment. A second Hausman test on a model that includes only investment to a model that includes both investment and population change yields a Chi-squared statistic of 371.42, meaning that I reject the null and conclude that the population variable is endogenous. Therefore, all of the IV models are based on the assumption that current investment is exogenous.

Table II-12 reports the results from models that are specified to control for endogeneity. I begin with a specification that embodies the findings above, a simple Solow model where investment is exogenous and population change is endogenous. I

instrument population change with a lagged value and find that both are significant and have the appropriate sign. The Kleibergen-Paap LM test shows that the model is not under identified. Following the “rule of thumb” of the Cragg-Donald and Kleibergen-Paap Wald F-statistic being at least 10 for weak identification to not be considered a problem (Baum et al., 2007) I find that this specification does not contain weak instruments. I then test the same model, but this time I use the initial value of population change, lagged five periods, as the instrument. Again the model passes the diagnostic test to ensure that it is not under identified or has weak instruments. A simple endogeneity test, as presented in Baum et al. (2007) yields a p-value of 0.081 confirming that population change is indeed endogenous. To validate this, I reverse the model and treat population change as exogenous and investment as endogenous, the endogeneity test yields a p-value of 0.148, verifying that investment is indeed exogenous and supporting the results of the Hausman tests above.

In the fourth specification I add the foreign oriented patent families to the model as an endogenous variable. The variable is significant, however, issues do arise. I fail to reject the null hypothesis in the Kleibergen-Paap LM test and conclude that the model is under identified. Also, both Solow determinants are no longer significant. However, when I test for the endogeneity of foreign oriented patent families I obtain a p-value of 0.120, indicating that the variable is exogenous. In the final specification I add human capital as an additional exogenous variable. The rationale for this is that when human capital is included as an endogenous variable and an endogeneity test (Baum et al., 2007) is performed, I fail to reject the null that the variable can be treated as exogenous. In this specification I find that the model is not under identified and the instruments are

not weak. Moreover, when I add initial GDP as an additional instrument (Durlauf, et al., 2005) I fail to reject the null that these instruments are uncorrelated with the main errors and therefore the model is not over identified. The main result of the model is that investment and my measure of innovative inputs, foreign oriented patent families, are both significant explanatories of labour productivity.

Table II-12 Modelling Endogeneity with Instrumental Variables

XTIVREG 2SLS Fixed- Effects Clustered by Countries	Solow	Solow II	Solow III	Solow w/ FOPF as Endogenous	MRW w/ FOPF and HC as Exogenous
Population Change			-0.009 (0.018)		
L1(Population change)	-0.025* (0.013)			-0.015 (0.030)	-0.023 (0.021)
L5(Population change)		-0.107* (0.063)			
Investment	0.477** (0.213)	0.732*** (0.217)		0.170 (0.113)	0.148** (0.063)
L5(Investment)			-0.052 (0.430)		
D(Human Capital)					0.593 (0.405)
L5(Foreign Oriented Patent Families)				0.117*** (0.037)	
Foreign Oriented Patent Families					0.062** (0.030)
Cragg-Donald Wald F	1630.04	22.23	25.50	145.77	867.79
Kleibergen-Paap Wald F	315.91	13.36	11.60	14.694	339.59
Stock-Yogo weak ID test critical values					
10% maximal IV size	16.38	16.38	16.38	7.03	19.93
15% maximal IV size	8.96	8.96	8.96	4.58	11.59
20% maximal IV size	6.66	6.66	6.66	3.95	8.75
25% maximal IV size	5.53	5.53	5.53	3.63	7.25
Kleibergen-Paap rk LM	11.775	7.283	4.279	1.831	10.005
Chi-Square(1) p-value	(0.001)	(0.007)	(0.039)	(0.176)	(0.007)
Hansen J Statistic					1.481
Chi-Square(1) p-value					(0.224)
Endogeneity Test	-	0.081	0.148	0.120	0.018
Chi-Square(1) p-value					
R ²	0.862	0.735	0.862	0.656	0.867
RMSE	0.0718	0.0787	0.0491	0.041	0.0376
Observations	608	508	515	269	378

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

6.5 Co-integration models

I now want to consider dynamic panel models as another way to explore the use of foreign oriented patent families as a measure of innovation input. Using co-integration techniques I control for: correlation over time, specific types of endogeneity, parameter heterogeneity and non-stationarity of variables over time. I investigate the long-run equilibrium relationship and short-run determinants of growth. Recent developments in co-integration econometric techniques implement panel data estimators that allow for heterogeneous slope coefficients across group members. Examples of this include the Mean Group (MG) estimator (Pesaran and Smith, 1995), the Augmented Mean Group (AMG) estimator (Eberhardt and Teal, 2010; Bond and Eberhardt, 2009) and the Pooled-Mean Group (PMG) estimator (Pesaran, et al., 1999, 2000). The PMG estimators rely on a combination of pooling and averaging of the estimated coefficients. The dynamic fixed effect (DFE) model of Pesaran and Smith (1995) is a model where all parameters, except intercepts, are constrained to be equal across panels. These techniques aid in the estimation of large N and large T panel-data models where non-stationarity may be a concern and are ideally suited for the data and models considered in this paper. That is, those with more than 15 cross-section and time observations. The models estimated in this paper typically include 26 countries over about 15 years, depending on the variables considered. For this exercise, I employ both the DFE and PMG techniques. The standard application of the PMG is preferred because the error correction mechanism (ECM) encompasses the 'right' specification. That is, if variables are $I(1)$ in levels and co-integrated, there will be evidence of error correction. If the variables are $I(1)$ but do not co-integrate, then the model does not have error correction.

The ECM term will be insignificant and what is left is an equation in first differences, which means the variables are stationary. For this reason, I do not need instruments for the type of endogeneity that arises when the independent variables are correlated with the unobservable variables or omitted variables. Alternatively, this can be understood as the long run relationship being consistent if the variables are co-integrated. This means that the estimate converges to the true population coefficient much 'faster' than in OLS. Endogeneity may be present, but it cannot distort the consistent co-integrating vector, implying that the estimates are not biased by omitted variables.

6.5.1 Dynamic fixed effects

Following the type of modelling conducted in previous sections I begin with a fixed effects model. In this type of model all parameters are constrained to be equal across panels, except the intercepts, which are heterogeneous. There is appeal to this model as it allows for specific time invariant variables not included in the set of variables to be 'accounted' for, albeit in a simplistic fashion. Table II-13 reports the results. I begin again with the traditional Solow model and find that investment has a positive and significant impact in the long-run equilibrium and in the short-run. Population change has a significant negative impact in the long run, as expected, but has a positive impact in the short run. However, the long run impact is fifty times as large as the short run impact. The results show a significant common dynamic process in all the models discussed below and this error correction term is significantly negative, which is required for these techniques (Blackburne and Frank, 2007). I then consider the MRW model and find that the relationships above hold and that human capital has a positive

and significant impact in the long-run equilibrium and in the short run it has a negative and significant impact. The short run impact is one tenth of the long run effect and may be reflective of education investment costs that do not yield returns in the short-run. However, the larger issue with this specification is that there is no significant common dynamic process.

I then turn to my key variable, foreign oriented patent families. Recognizing the issue with the human capital variable, instead of adding the patenting variable to the MRW model I add it to the Solow model. I find that the relationships in the Solow model hold and that the foreign oriented patent families variable has a positive and significant impact in the long-run equilibrium and in the short-run. I now want to look at the results when I normalize the patenting variable by population; that is, the number of foreign oriented patent families per capita. The results are virtually identical to the previous model. Finally, I consider a full model that includes human capital, government and openness. The specification includes government and patenting in the long run equilibrium along with the Solow determinants. I find that again the results of the first specification, the Solow model, in this exercise still hold. Government has a significant negative impact in both the long run and short run and patenting has a significant positive impact in both the long run and short run. Human capital has a negative impact in the short run. However, the long run impact did not remain in this specification. The key result is that my variable of interest foreign oriented patent families has a positive significant impact in both the short and long run in all specifications.

Table II-13: Co-integration Modelling – Dynamic Fixed Effects

XTPMG Dynamic Fixed Effects		Solow	MRW	Solow w/ FOPF	Solow w/ FOPF per capita	Full Model w/ FOPF per capita
LR	Population change	-0.501** (0.475)	-0.370*** (0.112)	-0.274*** (0.080)	-0.284*** (0.084)	-0.210*** (0.079)
	Investment	2.844*** (0.763)	2.028*** (0.446)	1.884*** (0.372)	1.977*** (0.399)	2.526*** (1.045)
	Human Capital		1.061** (0.492)			
	Government					-1.695** (0.759)
	Openness					
	Foreign Oriented Patent Families per capita			0.210*** (0.052)	0.226*** (0.058)	0.253*** (0.080)
	Constant					
SR	Population change	0.011*** (0.002)	0.011*** (0.002)	0.010*** (0.002)	0.010*** (0.002)	0.006*** (0.002)
	Investment	0.234*** (0.0188)	0.220*** (0.0193)	0.224*** (0.018)	0.224*** (0.018)	0.125*** (0.020)
	Human Capital		-0.123** (0.054)			-0.083* (0.048)
	Government					-0.310*** (0.044)
	Openness					0.051 (0.032)
	Foreign Oriented Patent Families			0.015* (0.008)	0.015* (0.008)	0.014** (0.007)
	Constant	0.013 (0.044)		0.071 (0.052)	0.112* (0.058)	0.144** (0.071)
	Common Dynamic Process	-0.015*** (0.005)	0.026 (0.043)	-0.027*** (0.007)	-0.026*** (0.007)	-0.021*** (0.006)
	Log-Likelihood					
	Observations	299	299	299	299	299

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

6.5.2 Pooled mean group

The PMG estimators have a common long-run coefficient for all countries, but the short-run and error correction term are allowed to differ across countries. The OECD countries are likely to follow the same equilibrium relationship in the long-run and therefore the PMG model is of interest. Like the DFE model, this type of model does not account for cross-sectional dependence, but it does account for the type of endogeneity that is concerned with omitted variables. Table II-14 reports the results of

the PMG specifications. The Solow model has a significant error correction term and the long-run relationship is consistent with expectations: investment has a significant positive impact and population growth a significant negative impact on labour productivity. Investment also has a positive and significant impact in the short-run. I do not get the positive significant impact of population change in the short run that was present in the DFE specifications. In the MRW specification I find that investment and human capital both have a significant positive impact. Population change is not significant in the short or long run. Like the DFE specification of the MRW model human capital has a significant negative impact on labour productivity. However the error correction term is not significant. Recall that the human capital variable is a five-year average of a variable that is only measured every five years. This creates some undesirable mathematical properties when there is no change in the value between two measurements. Specifically, the first-difference for five observations will be zero. The result is that there are concavity issues and convergence fails.

When I add my patent variable to the model the error correction term is again significant. I find that the Solow determinants are again significant and take on the expected values. Additionally, foreign oriented patent families have a positive significant impact on labour productivity in the long run. When I control for government size, openness and human capital I find that the measure of foreign oriented patent families is significant in the long-run relationship, along with human capital, investment, government and population growth, with expected signs. In the short run investment has a significant positive impact and government a significant negative impact. I now want to look at the results when I normalize the patenting variable by

population; that is, the number of foreign oriented patent families per capita. In the Solow plus patents specification I find that the error correction term is not significant. Despite this I note that my patent variable is significant in the long-run. In the full model specification I find that again my key patenting variable has a positive and significant impact. Investment, population and human capital are all significant and have the signs that theory suggests. Identical to the previous specification, investment has a significant positive impact and government a significant negative impact in the short run.

The results suggest that investment is the key determinant of growth for this set of countries as it is significant in the long and short run in all of the specifications explored in the DFE and PMG models. However, my measure of innovative inputs, foreign oriented patent families, is significant in each specification it is introduced.

Table II-14 Co-integration Modelling – Pooled Mean Group estimates

XTPMG Pooled-Mean Group Estimators		Solow	MRW Davidon- Fletcher- Powell (DFP) algorithm	Solow w/ FOPF	Solow w/ FOPF per capita	Full Model w/ FOPF	Full Model w/ FOPF per capita
LR	Population change	-1.505*** (0.475)	-1.262 (0.805)	-0.231*** (0.021)	-0.145*** (0.016)	-0.088*** (0.009)	-0.114*** (0.010)
	Investment	9.311*** (2.312)	9.460* (5.429)	0.853*** (0.037)	2.479*** (0.127)	0.799*** (0.054)	0.999*** (0.050)
	Human Capital		12.660* (6.505)			0.418*** (0.095)	0.433*** (0.098)
	Government					-0.399*** (0.068)	
	Openness						
	Foreign Oriented Patent Families per capita			0.304*** (0.014)	0.624*** (0.046)	0.286*** (0.015)	0.347*** (0.0219)
SR	Population change	0.045 (0.030)	0.076 (0.058)	-0.037** (0.018)	0.063 (0.050)	-0.101 (0.113)	-0.103 (0.114)
	Investment	0.170*** (0.042)	0.237*** (0.033)	0.199*** (0.038)	0.197*** (0.040)	0.133*** (0.041)	0.138*** (0.043)
	Human Capital		-2.219** (1.089)			-0.101 (0.113)	-0.111 (0.705)
	Government					-0.191** (0.091)	-0.211** (0.084)
	Openness					0.069 (0.076)	0.062 (0.073)
	Foreign Oriented Patent Families			-0.014 (0.215)	0.011 (0.021)	-0.024 (0.016)	-0.016 (0.012)
	Constant	-0.120*** (0.050)	-0.117 (0.103)	0.171* (0.091)	0.068** (0.031)	0.327*** (0.100)	0.309*** (0.101)
	Common Dynamic Process	-0.006*** (0.003)	-0.003 (0.002)	-0.037** (0.018)	-0.012 (0.009)	-0.062*** (0.0186)	-0.044*** (0.0151)
	Log-Likelihood	1340.453	1405.076	1415.558	1411.765	1667.965	1668.218
	Observations	299	299	299	299	299	299

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

The conclusion of these results is that as I remove the assumptions of heteroskedasticity, endogeneity, stationarity, serial correlation and cross sectional correlation; foreign oriented patent families have a consistently significant positive impact on labour productivity in OECD countries.

7 Conclusion

In this paper I have revisited the use of patent data in productivity and growth models. Specifically, I investigated the hypothesis that innovation is an important determinant of growth in advanced economies that enjoy all the benefits of economies of scale and gains from trade. To do this I tested various measures of patenting in a traditional Solow model, an augmented Solow model as suggested by Mankiw, Romer and Weil and a fuller specification that includes variables explored by Barro, Sala-i-Martin and Durlauf. I find that the new measure of patenting, foreign oriented patent families, is statistically significant in most specifications, even as I control for heteroskedasticity, cross-sectional dependence, serial correlation and endogeneity. With respect to the parameter estimates, I find that the impact of patenting is between one-tenth and one-half of that of investment in the models where both are significant. Using a dynamics fixed effects model I am able to establish that there exists a long-run equilibrium that is determined by population change, investment, human capital and innovation, as measured by foreign oriented patent families. In the short-run investment, investment and size of government influence deviations from equilibrium. The implication of these results is that while traditional investment is the most important determinant of labour productivity, innovative knowledge of the type described by Jaffe and Trajtenberg (1998) also plays an important role in the long-run and foreign oriented patent families perform well as a measure for innovative inputs.

These results should reinforce the importance to governments across the OECD that in order to remain competitive vis-à-vis their peers and to offer an increased

standard of living for their citizens they should pay close attention to their innovation policies. The creation of a national innovation and intellectual property (IP) strategy would be a good starting point. This should be based on providing a strong IP framework that provides the incentives to patent internationally and at the same time encourages open and collaborative innovation, where appropriate. In order to facilitate international patenting governments should work harder at harmonizing administrative process and legal frameworks. This would link the above strategy to the needs of exporting and high growth firms, which is important as these are a natural source of job creation and economic growth in the most advanced economies.

It should be acknowledged that innovation and knowledge creation occur outside of patenting and that because innovation itself cannot be observed directly the contribution of a better measure of patenting to growth empirics faces challenges that have yet to be overcome. This study is then intended to advance our understanding of the role of patenting in relation to productivity and economic growth, while recognizing that much still needs to be done.

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9 Appendix

9.1 Alternative measure of foreign oriented patent families

Table II-15 2011 Measure of Foreign Oriented Patent Families

All models XTREG FE with year dummies	MRW + FOPF (2011) 5 - year average of variables	MRW + FOPF (2011) 6 - year average of variables	MRW + FOPF (2011) 7 - year average of variables	Full + FOPF (2011) 5 - year average of variables	Full + FOPF (2011) 6 - year average of variables	Full + FOPF (2011) 7 - year average of variables
Population change	-0.001 (0.007)	-0.005 (0.005)	-0.008 (0.006)	0.006 (0.009)	-0.001 (0.004)	-0.008 (0.006)
Investment	-0.064 (0.061)	0.003 (0.070)	0.040 (0.098)	-0.048 (0.064)	0.001 (0.077)	0.017 (0.105)
Human Capital (D – 1)	0.643*** (0.203)	0.807*** (0.268)	0.431 (0.329)	0.413* (0.208)	0.417 (0.262)	0.132 (0.346)
Government				-0.359*** (0.109)	-0.266** (0.119)	-0.276 (0.167)
Openness				0.158* (0.092)	0.064 (0.103)	-0.028 (0.143)
Foreign Oriented Patent Families	0.111** (0.048)	0.118** (0.058)	0.110 (0.081)	0.080* (0.043)	0.100* (0.059)	0.090 (0.086)
Constant	3.11*** (0.514)	2.83*** (0.605)	2.74*** (0.836)	3.44*** (0.769)	3.30*** (0.913)	370*** (1.221)
R ² - Within	0.834	0.835	0.793	0.877	0.852	0.793
R ² - Between	0.026	0.029	0.032	0.001	0.036	0.032
R ² - Overall	0.016	0.021	0.037	0.000	0.027	0.037
Rho (variance due to u _i)	0.997	0.999	0.999	0.997	0.998	0.999
Observations	91	73	55	91	73	55

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

PART III

Increasing Rival Costs: Trade-mark Opposition as a Tool for Entry-Deterrence

Abstract: Very large incumbent companies have at their disposal a number of ways to increase the cost of entry for potential entrants. Advertising related expenses are one of the cost items that are relevant to barriers to entry. However, there is little empirical evidence to this effect. Trade-marks are central to a company's advertising strategy. Within the *Trade-marks Act* of Canada there is a mechanism by which companies may contest a new trade-mark. In this paper, I use a new and unique dataset from the Canadian Trade-mark Opposition Board (TMOB) to test whether very large incumbents are using the trade-mark opposition process strategically to deter entry by new companies. I regress the relative size of the opponent to the applicant in a trade-mark opposition, the absolute size of the opponent and whether the opponent is an incumbent on the likelihood that they will delay the process and the likelihood they will be successful. At the same time I control for the size of the trade-mark applicant, the experience of both the opponent and applicant and the industry of the opponent. My results show that very large companies use more extensions of time to delay the process and that they are more likely to be successful in opposing a new trade-mark. This provides evidence of the strategic use of the trade-mark opposition process as a way to increase the cost of potential entrants and thereby creating barriers to entry.

1 Introduction

Increasing the costs of a rival is a key strategy for companies who wish to deter entry into a market where they are established (Dixit, 1980). In his important contribution to entry-deterrence literature, Dixit (1980) argues that an established company can deter entry by altering either initial conditions or the rules of the post-entry game and that it does this through investment in capacity. What is of particular interest to this paper is the idea that capacity can be understood in terms of advertising, a point made explicitly by Dixit (1980). This is reinforced in Salop and Scheffman (2005) where they show that advertising expenses could be used to raise rival's costs and that the strategy could be independent of demand-increasing motives. That is; raising costs for the entrant has benefits that exceed the cost if the strategy allows the large incumbent to increase prices going forward.

I intend to use these assertions as the basis of an empirical investigation into whether large firms over-invest in branding to deter entry. The central component of any advertising campaign is brand recognition. A company's trade-mark portfolio is one of its most important assets and can have a large impact on the demand for its products (Sappington and Wernerfelt, 1985). Can consumers easily identify your products and distinguish them from those of your competitors? Given the importance of branding, it is then no surprise that obtaining a trade-mark is also central to a company's advertising strategy. There has been an increased interest in trade-marks in recent years as it is increasingly recognized that advertising and marketing are becoming key components of a company's strategy (Ramello, 2005; Ramello, 2006).

A recent case *Industries Lassonde inc. c. Oasis d'Olivia inc.*, in the Provincial Court of Appeals from Quebec, Canada, presents the finding that at least one company actually used their trade-mark(s) to extend market power above what could legally be expected from that right. In that case the judge ruled that the company in question used its economic power and experience as a “*shotgun approach to attack [...] simultaneously on several fronts with their full might, attempting to [...] intimidate and thwart the applicant from its legitimate use of its trade name and trade-mark*”. He went on to state that “*Such menacing and abusive conduct cannot be condoned without impunity*”.

In this paper I introduce a unique data set on completed trade-mark opposition cases between 1996 and 2009. I use logit models where I regress the relative size of the opponent to the applicant in a trade-mark opposition, the absolute size of the opponent and whether the opponent is an incumbent on the likelihood that they will delay the process and the likelihood they will be successful. At the same time I control for the size of the trade-mark applicant, the experience of both the opponent and applicant and the industry of the opponent.

Section 2 provides an overview of trade-marks, including their function, the economic rationale for their existence, and the costs and benefits of trade-mark rights. Section 3 introduces trade-mark related strategies to increase entrant costs. Section 4 presents the trade-mark opposition process, strategies and empirical results to date. Section 5 describes the data and methodology presented in this paper. Section 6 presents the results and subsequent discussion. Section 7 concludes.

2 An Overview of Trade-Marks

2.1 Why are trade-marks important?

When one thinks of intellectual property rights the first thing that comes to mind for most individuals are patents, the second is copyrights and frequently trade-marks are an afterthought. After all, is a trade-mark not simply a registered name or logo? How can it be considered a property right? This position has been reflected in the literature, where it has been claimed that trade-marks have less economic importance than other intellectual property rights since they protect only a name, not a product or a method of conducting business (Lavey, 1982). Despite common perception, it is widely regarded that trade-marks themselves are valuable. The average award or settlement in the top five trade-mark cases in the U.S. between 1990 and 2005 was almost \$100 million and the average cost of a trade-mark litigation case in the U.S. in 2003 was \$600,000 (Hoti et al., 2006).

Trade-marks, it is argued, create barriers to entry in their primary market through differentiation, and in their secondary or tertiary markets through brand extension (Hirshhorn, 2010). It is therefore no surprise that some companies have developed complex and in some cases aggressive trade-mark strategies. There is also growing acknowledgement that consumers have become much more aware of the branding strategies of companies (Olszyk, 2005). What is surprising is that even though there are costs associated with a trade-mark infringer who seeks to 'free-ride' on the reputation or goodwill of a trade-mark owner most governments do not monitor for this primarily because they do not have a comparative advantage in monitoring (Mealem et al., 2010).

For example, in Canada this is the case and companies monitor infringement, not the government. However, the Federal Government does publish approved trade-marks in the Trade-marks Journal, which is published weekly and is widely distributed. Outside parties have up to two months to oppose a trade-mark to the Trade-Mark Opposition Board. It is the over expenditure in the opposition process by large firms that will be investigated in this paper.

2.2 Trade-marks Defined

Trade-marks are the simplest and, along with trade secrets, the oldest form of intellectual property. They have historically appeared in some form in most societies around the world. Trade-mark usage predates the information age by a thousand years (Ramello and Silva, 2006). In the legal sense a trade-mark is a word, or words, a design, or a combination of these, used to identify the goods or services of one person or economic entity and to distinguish these goods or services from those of others in the marketplace. Registered trade-marks provide *prima facie* evidence of ownership and exclusive rights of use. Registration of a trade-mark in Canada gives an exclusive right to its use throughout Canada under the *Trade-marks Act* (CIPO, 2012). Trade-marks can be maintained indefinitely as long as the appropriate administrative fees are paid and the company can prove it is using the mark. The value of a strong trade-mark is often unappreciated. A great example of this is that if all of the tangible assets of Coca-Cola, that is factories and inventories, were lost, the company could leverage the intangible asset of its trade-mark portfolio, valued at \$71.9 billion⁸, as security to acquire funds

⁸ <http://www.interbrand.com/en/best-global-brands/best-global-brands-2008/best-global-brands-2011.aspx>

(Cohen, 1986). Trade-marks also act as a signal for economic activity (USPTO, 2009). It is therefore not surprising to see that trade-mark filings closely follow markets (see figure III-1, Data from OECD and CIPO). Of note is the drop in trade-mark applications during the periods of: stagflation from 1973-75; the 1979 energy crisis that lead to the recession of the early 1980's; the saving and loan crisis of 1986, the recession in the early 1990's; the dot-com bubble burst of the early 2000's and of course the recent financial crisis in 2008-09. In the following sub-sections, I explore trade-marks more deeply, including the function of a trade-mark, the economic rationale for the existence of trade-marks and the intellectual property strategies of companies.

Figure III-1 Trade-marks and Economic Activity

2.3 The function of a trade-mark

The function of a trade-mark is to identify the producer of a product or service in such a way that consumers can easily differentiate it from competing brands (Posner, 2005). In this way it protects investment in branding and corporate identity, while at the same time reducing search costs for consumers. To expand on this point the three primary functions of trade-marks are (Chen, 2002):

1. To prevent other companies from adopting similar marks for their products or services
2. To provide a warranty of product quality
3. To allow for promotion of the product

The first of these functions is straightforward in that it is in the best interest of a well functioning free market economy that companies are not allowed to directly copy the marks associated with the products and services of other companies. This undermines the basic incentives to even commence production and in the absence of production there is no economy. While competition is a necessary component of a well functioning market economy, it is enhanced by product imitation, not brand imitation (Handler, 1996). Therefore, a trade-mark is intended to minimize copying of the name or brand associated with the product. Many companies make pens, but only one can use the label *Bic*.

The second function, to provide warranty of a product, is a public good that emanates from a sound trade-mark regime. By allowing consumers to link products to companies, trade-marks provide consumers first with confidence in the product and second with a means of retaliating when issues of quality or safety arise. The economic

costs of such retaliation will exceed the damage to the individual consumer as demand for not only the product in question may decrease, but depending on the severity of the situation, demand for other products that the company sells may decrease as well (Choi et al. 1996; Ramello and Silva 2006). Therefore, the incentive to ensure quality is strong.

The third function of a trade-mark is to allow companies to effectively promote their products. A strong trade-mark or brand allows a company to differentiate its product from those of existing or potential competitors. This allows the company to be confident that it will benefit from its investment in quality and the advertising and marketing needed to capitalize on it. Product differentiation has become perhaps the most important modern use of trade-marks and has led to huge investments in advertising and marketing (Ramello and Silva, 2006).

2.4 The rationale for the existence of trade-marks

The economic rationale for trade-marks is based on ideas from the seminal work of Arrow (1962) arguing that there exists a market failure in the production of information and that intellectual property rights provide a remedy for that market failure. Intellectual property rights stimulate the production of new ideas and competition through the conferring of market power. However, this market power can also create rent seeking behaviour that distorts the competitiveness of the market. The net result of these two offsetting effects is the source of the tension found in the literature that debates the merits of not only stronger or weaker intellectual property rights, but sometimes the very existence (Ramello, 2005).

2.5 The economic benefits of trade-marks

Trade-marks create information that reduces consumer search costs and facilitates exchange, resulting in increased trade (Ramello, 2006). Not surprisingly, it has been shown that trade-marks are positively correlated with the growth of trade (Ramello and Silva, 2006). Essentially trade-marks aid in the correction of information asymmetries and are therefore a solution to the type of market failure described by Arrow (1962) where follower companies can free-ride on the investment in product reliability and hence good will won by the leader in that market (Ramello and Silva, 2006). Trade-marks provide the incentive for companies to invest in information that distinguishes the quality of their production, generating a brand name that protects the investments needed to grow to minimum efficient scale. Achieving efficient scale provides social welfare gains for consumers and producers (Hirshhorn, 2010). While I argue below that trade-marks can be used anti-competitively, the fact that trade-marked brands are sold at higher prices does not in itself mean that trademarks are anti-competitive, since it ignores the savings in the search costs of consumers that an established brand brings (Posner, 2005). Finally, as noted above, trade-marks deter companies from providing a lower quality product than promised because the trade-mark exposes the company to damage (Choi et al., 1995). This has a social welfare benefit to the economy.

2.6 The economic costs of trade-marks

Companies use strategies to leverage the legal structure of their property right to their advantage. To the extent that a company can end 'free riding' on its brand, it can enhance its market power. In the limit, if all forms of brand competition can be eliminated, the cost can become large (Lemley and McKenna, 2010). By preventing free-entry or competition, the market power that trade-marks confer causes inefficiency and distortion in resource allocation. The result is that the information benefit of the trade-mark is at least partially offset by the costs associated with this barrier to new competition (Medonça et al., 2004). However, it should be understood that the emergence of large-scale companies, which reach minimum efficient scale due to a strong brand or trade-mark is not necessarily negative (Ramello, 2006). Rather, it is a realization that a trade-mark impacts market structure, and by extension the behaviour of companies and consumers (Nicita et al., 2005; Ramello, 2006). It is then the existence of market power, or monopoly rents, which provides the incentive for followers to enter the market by improving upon rather than simply imitating leaders who dominate the market (Nicita et al., 2005). That is, a trademark is the legal instrument that is intended to reduce one form of 'free-riding' while at the same time providing an incentive to increase competition along another margin. On the other hand, the market power enjoyed provides the incentives for an established company to extend the protection from rivalry given by trademarks into other markets; this is known as brand stretching. Brand stretching, or the use of an established trade-mark to launch a new, sometimes unrelated product, is often seen as a way for a monopoly company to extend its market power into a new market (Pepall and Richards, 2002). It can be seen that when the

market of ideas has been protected from 'free-riding' through the proliferation of intellectual property rights, it can become burdened by high transaction costs (Ramello, 2005).

The recent expansion of trade-mark rights in law (e.g., geographical indicators⁹) has served to amplify the arguments for the negative aspects of trade-marks. It has been suggested that this is especially true when trade-marks become an item of consumption, with low inter-changeability due to uniqueness, as the strengthening and extension of appropriability coincides with an increase in market power (Ramello and Silva, 2006). Finally, there is question whether there is a logical, economical or historical support for the idea that giving a leader, with a trade-mark in one market, the power to control all uses of it everywhere. In short, owning a mark does not equate to owning a market (Lemley and McKenna, 2010). Alternatively we should not treat a trade-mark the same as a copyright or patent; rather followers should be able to share in the goodwill of a product, say cell phones, but not in the goodwill of the producer, say Apple (Handler, 1996).

To summarize it is clear that there are economic costs and benefits associated with trade-marks. The common retort by economists to the statement that trade-marks are a source of market power and barriers to entry is that they provide information and reduce search costs and any pricing above competitive levels reflects the value of the trade-mark. Furthermore, it is only when entrants lack valuable assets to use as collateral and; capital markets are seriously imperfect, that an incumbent could actually

⁹ Geographical indications are place names (in some countries also words associated with a place) used to identify the origin and quality, reputation or other characteristics of products (for example, "Champagne", "Tequila" or "Roquefort"). World Trade Organization
http://www.wto.org/english/tratop_e/trips_e/gi_e.htm

use their position as leader in the market to deter entry (Schmalensee, 1974). The rebuttal to this is that capital markets are indeed imperfect and investments in advertising are risky. This is especially true for a new company who has submitted a trade-mark that may be at risk for opposition. Moreover, there are questions as to whether the minimization of search costs is necessarily efficient, especially if the trade-mark reduces searches to the point where social welfare enhancing price-quality matches are not found (Feinberg, 1985). The intent of this section is not to answer the above questions, but to provide the necessary foundation to understand the incentives for companies to use the trade-mark opposition process as a way to increase the costs of potential entrants.

3 Trade-marking Strategies to Increase Entrant Costs

Below is a list of four recognized trade-mark associated strategies companies use to deter entry into a given market. Each of these will increase the actual or perceived costs of potential entrants. The following are a subset of the list of motivations behind trade-marking for companies presented in Medonça et al. (2004). These were selected from the broader set as they are more closely aligned with the behaviour of interest in the study.

1. Create inelastic demand through product differentiation to allow for pricing above marginal cost
2. Improve appropriability of innovation when other intellectual property rights are not effective or expire

3. Entering new product or service markets with an existing mark or brand stretching
4. Save on promotion expenditures by building reputation.

The first, to create inelastic demand, is the key to branding. Branding, by definition, has as its objective the creation of market power by creating a reputation for a product or service. This reduces the inter-changeability of products and services, increasing the inelasticity of the demand. The result is that the price that consumers are willing to pay for the product or service increases (Aaker, 1996). It is clear that trademarks help leading companies to first establish and then maintain their dominant position (Hirshhorn, 2010). Market power can be achieved through the advertising of differentiated products and this has led to huge investments in advertising and marketing (Ramello and Silva, 2006). The ready-to-eat cereal industry is an example of the use of product proliferation by established brands to maintain market power. Between 1980 and 2002 there have been over 1000 cereal products from about 40 companies. However, the top 5 companies accounted for more than 90% of the output despite selling at prices that were about 1.7 times that of companies that did not have established brands (Hirshhorn, 2010). As companies follow stronger strategies of differentiation the result, in the limit, is that once a product is totally differentiated the company has a *de facto* monopoly (Dixit, 1979; Singh and Vives, 1984). This is the same objective as creating inelastic demand. A potential entrant is therefore required to spend significantly more in advertising investments in a market where established products were totally differentiated in order to attract consumers.

The second strategic objective is to improve appropriability when other intellectual property rights are not effective or are expiring. Intellectual property rights do not immediately and perfectly give market power to their holders; rather it is the market structure that determines profitability. It is the company's ability to wield market power that gives intellectual property rights their value (Nicita et al., 2005). A great example of when a trade-mark may not be perceived as an intellectual property right itself, but rather as a tool or method to create or extend a right, is when a brand name drug's patent expires, but consumers are still willing to pay a premium, based on the trade-mark, even though an identical generic alternative is available at a lower price (Posner, 2005). The 'good will' that the brand name pharmaceutical company has built up with its consumers allows for pricing above marginal cost, despite the existence of competition. In this case a potential entrant will need to increase its advertising investment to persuade consumers that their product is of similar quality.

The third strategy, to use an existing trade-mark to move into new product markets is important. This is known as brand stretching and it most often involves entry by an established company into a secondary market that is competitive; that is, it includes many incumbent companies (Pepall and Richards, 2002). Brand stretching accounted for almost half of all new packaged goods in the 1980s and the growth of large multi-national companies has likely lead to an increase of brand stretching (Tauber, 1988; Choi, 1998). Having significant market share in a large market is more effective in brand strength than the same, or higher, market share in a small market (Pepall and Richards, 2002). The key insight into the strategy of brand stretching is that the power of brand recognition does not necessarily come from the trade-mark being

identified for a specific feature, for example quality, but from being known to consumers. Simply put, consumers prefer products that are popular over those that are not (Pepall and Richards, 2002). This is the 'keeping up with Jones' phenomenon, where it is recognized that individuals compare themselves to others in the accumulation of goods. This increases the costs of the existing competitive companies, as well as any future entrants, as these companies then need to invest in advertising beyond what would have been required in the absence of the large company 'stretching' its brand.

The fourth strategy is an extension of the previous strategy, but also includes scenarios where new products are released into markets where the company is already established. This is because brand stretching allows for a price advantage to a company, as the information and goodwill for the new product is much cheaper than starting a new brand (Choi, 1998). Brand stretching provides economies of scope in the introduction of new products, as consumers perceive the same guarantee of quality associated with the original product. This results in lower advertising or marketing costs (Choi et al., 1995). For example; during the 1980s introducing a product through brand stretching cost on average \$50 million, compared to \$150 million when a product was introduced with a new brand name (Tauber, 1988). Multi-product companies who are engaged in brand stretching enjoy information spillovers that provide incentive to maintain quality levels in all of their products. The resulting reputation can provide a competitive advantage over single product market companies or other potential entrants with an unlinked product (Choi et al., 1995). It is safe to say that the investments described above have likely doubled or more since the 1980's, and therefore small companies will not be able to match the level of advertising investment.

4 Trade-mark Oppositions

The *Trade-marks Act* in Canada includes a mechanism whereby a third-party, the opponent or incumbent, may object to the registration of a trade-mark in Canada by an applicant or entrant. Of note is that while a successful opposition prevents a trade-mark from being registered, it does not prevent an applicant from using that mark in Canada. Only the courts can prohibit a party from using a mark. Opposing a trade-mark can be seen as delaying the registration of a trade-mark. The trade-mark opposition process has a number of key steps: specifically, filing a statement of opposition; sharing of evidence; cross-examination and decision, which may or may not be made in an oral hearing. In each of these steps it is possible for each party to request extensions of time and these serve to further delay the process. It is of interest that only about 10% of all cases go to the decision stages. The remainder of the cases are settled by the parties. This is encouraged by the Trade-marks Opposition Board (TMOB), who sees this as a preferred outcome if parties are able to come to an agreement. However, one of the issues of concern is that larger companies, with deeper pockets, may use stalling tactics, through repeated use of extensions of time, to force cash strapped smaller or younger companies to withdraw from the registration process.

The grounds for filing an opposition are outlined in section 38 of the *Trade-marks Act*. Specifically they are as follows:

38. (1) Within two months after the advertisement of an application for the registration of a trade-mark, any person may, on payment of the prescribed fee, file a statement of opposition with the Registrar.

(2) A statement of opposition may be based on any of the following grounds:

(a) that the application does not conform to the requirements of section 30;

- (b) that the trade-mark is not registrable;
- (c) that the applicant is not the person entitled to registration of the trade-mark; or
- (d) that the trade-mark is not distinctive.

Section 30 of the Act is an important consideration when considering the grounds for opposition. Annex A includes the full text of the section. Many of the requirements in section 30 are simple formalities to the procedure and are not considered contentious. Examples include: place of business and drawing of the trade-mark. The sub-sections of section 30 that are common grounds for opposition are (Mesiano-Crookston, 2007):

30(a) a statement in ordinary commercial terms of the specific wares or services in association with which the mark has been or is proposed to be used.

Grounds under 30 (a) that the applicant has not adequately described the wares or services with which they plan to use the trade-mark:

30(b): in the case of a trade-mark that has been used in Canada, the date from which the applicant or his named predecessors in title, if any, have so used the trade-mark in association with each of the general classes of wares or services described in the application.

Grounds under 30 (b) are that the applicant has not used the mark from the date they stated in the application.

30(i): a statement that the applicant is satisfied that he is entitled to use the trade-mark in Canada in association with the wares or services described in the application.

The substantive opposition under section 30(i) does not attempt to prove the applicant did not include such a statement, but focuses rather on the fact that the statement was not properly made. That is, that the applicant could not have been satisfied that they were entitled to use the trade-mark in Canada in association with the wares or services described in the application.

An illustrative example of the trade-mark opposition process begins with a company or individual filing, call them company A, a trade-mark application at CIPO. Once the application has been examined and it has been determined to be able to be registered, CIPO will publish the trade-mark in the Trade-mark Journal. Another company or individual, call them company B, will be monitoring the Trade-mark Journal on a regular basis as part of their strategy to protect their brand. Company B decides that the trade-mark put forward by Company A is too similar. They have up to two months to decide whether or not they wish to oppose the trade-mark. Between 2008 and 2011, 3% of the annual trade-mark applications at CIPO were opposed, an average of 1400 per year. If company B decides to proceed they must file a statement of opposition to CIPO. In this statement they must declare the grounds for the opposition. Company A then must decide whether they wish to file a counter-statement. If company A submits a counter statement then the proceeding moves to the evidence phase. At this stage parties submit their evidence to make their respective cases. If either party fails to provide evidence then they are deemed to have exited the process. There is an opportunity to amend the application made by company A, if they so desire and feel that this could satisfy the claims of the opponent. A cross-examination phase follows where parties can ask questions to clarify the position of their adversary in the process. At each of these stages there are opportunities to file for extensions of time. If the parties have not settled to this point then the case moves to the decision phase. About 1 in 10 opposition cases reach the decision stage. Either party may request that a hearing take place, if neither do then the TMOB will decide the case on the facts that

have been submitted by the two parties. Once a decision has been rendered by the TMOB, parties can appeal to the Federal Court of Canada.

4.1 Why oppose a trade-mark?

Those that are seeking a trade-mark in a country are doing so to either enter a specific geographic market as a new company, to introduce a new product in an existing market or to create a new market altogether (Sandner and Block, 2011). When intellectual property rights provide the appropriate incentives for innovation they give the holder an exclusivity that provides a level of market power that will impact the competitive structure and organization of that industry (Nicita et al., 2005). An entrant may benefit from the goodwill established by the leader by creating a trade-mark that is very similar to the incumbent's in hopes of free-riding on the market reputation created by the leader. Empirical evidence shows that entrants can significantly benefit from their ability to use an established trade-mark and this use will, in general, impede the expansion of the leader (Lemley and McKenna, 2010). Therefore, the strategy of opposing a trademark application can not a priori be interpreted as either 'good' or 'bad'.

A company that is already in a particular market, an incumbent or leader, may not want the added competition in that particular market. At the same time, the leader may attempt to discourage entry by signalling to potential entrants that a higher required level of advertising is needed to establish brand recognition. In addition entry costs can be further increased by requiring the entrant to defend its trade-mark application. This can be considered as using existing monopoly power, through spending of monopoly

profits and its position as a market incumbent, as ways of excluding small or young companies from entering markets. There are two main strategies that a company could use in a trade-mark opposition that signal to potential entrants a requirement for increased costs:

1. Establish a reputation for aggressive opposition, and;
2. Delay the opposition process to increase the cost of entry.

The first strategy can be illustrated by the von Graevenitz (2007) study where European data from the Office of Harmonization for the Internal Market (OHIM) was used to show that market leaders can benefit from a reputation for tough opposition and that this induces applicants to settle more readily (von Graevenitz, 2007). The value of a company's trade-mark, or trade-mark portfolio, will increase if a company can develop a reputation for aggressive opposition (von Graevenitz, 2007; Sandner and Block, 2011). A large company can also leverage their 'deeper' pockets to induce smaller potential entrants to withdraw. Essentially a larger company can be much more aggressive in opposing potential entrants. The artificial costs to potential entrants that can prove to be burdensome include the allocation of additional resources to the trade-mark opposition process and in some cases having to provide evidence (Sandner and Block, 2011).

The second strategy is concerned with the use of delay tactics through extensions of time. Filing a trade-mark opposition allows a leader to potentially weaken a follower's branding strategy and to delay the arrival of the rival in the market (Sandner and Block, 2011). The costs of delay in the opposition process can be substantial if the follower has made a significant investment in a marketing campaign based on the

desired trade-mark or if the follower is required to provide evidence in a lengthy adjudication proceeding (von Graevenitz, 2007). In Canada, each party to an opposition pays their own respective costs and the cost of delay or providing evidence is not shifted to the loser of a trade-mark opposition case. The Trade-mark Opposition Board has no authority to award costs in opposition proceedings (Mesiano-Crookston, 2007; von Graevenitz, 2007). Therefore, the longer the proceedings the more taxing it will be for smaller companies, relatively speaking. Therefore, it should not be surprising to find that larger companies who are incumbents use delays more often in an effort to deter entry. If they are more likely to win an opposition case, then this may be of concern.

4.2 The hypotheses to be tested

An investment in advertising, including the opposition to trade-marks that may have a negative impact on an incumbent's brand name or an entrant's future profits, is an important strategic decision for incumbent companies. Potential entrants may feel they are required to expend a similar amount in order to gain recognition and be profitable in the market. In this sense they face increased fixed and set-up costs. Currently there is little empirical evidence on whether these strategies have been used. My objective in this paper is to identify whether there is evidence of any of the strategies described above. I use a new and unique dataset from the TMOB to test whether very large incumbents are using the trade-mark opposition process strategically to deter entry by new companies.

Hypothesis 1: Larger companies who are incumbents will use delays more often as an opponent in a trade-mark opposition process.

Under hypothesis 1 I expect to find that the relative size between opponent and applicant, the absolute size of the opponent and whether they are an incumbent to have a positive impact on the likelihood of using a delay in the opposition process. The alternative to hypothesis 1 is that there is no strategic use of delays. In this case, I expect to find that the relative or absolute size of the opponent does not have a significant positive impact on the likelihood of the use of delays in the opposition process.

Hypothesis 2: Larger companies who are incumbents are more likely to win in a trade-mark opposition process.

Under hypothesis 2 I expect to find that the absolute size of the opponent and whether they are an incumbent to have a positive impact on the likelihood of the opponent being successful in the opposition process. The alternative to hypothesis 2 is that the outcome of the trade-mark opposition process is independent to the absolute size of the opponent and incumbency. In this case, I expect to find experience to be the likely determinant of success.

With respect to the control variables I expect that in a well functioning process experience leads to the use of fewer delays as participants became more familiar with the trade-mark opposition process. The work of von Graevenitz, (2007) suggests that a reputation for aggressive opposition leads to increased success. In my models I expect that experience does not lead to fewer delays for the very largest companies.

Furthermore, I expect that experience increases the likelihood of success in the process for either party.

It is impossible to get data on unopposed trade-marks that are advertised. Therefore, the empirical analysis begins after the opposition has been filed. For this reason I can say that one delay has already occurred in the process of obtaining a trade-mark. What I am testing is whether the use of extensions of times, called delays hereafter, is a strategy used by larger incumbents to deter entry and whether or not they are successful. The following section presents the data that will be used to test the two hypotheses put forward.

5 Data

The data set I employ is a unique set extracted from the TMOB of CIPO. It includes all completed opposition cases from 1996 to 2009. There were 25,201 such cases. I then matched the data with the OneSource: North American Business Browser database to extract company information. This included revenues to measure size and industry classification codes. There were 2575 cases where the applicant and opponent could be matched. I use these 2575 as my sample.

5.1 Definitions of variables used

Table III-1 provides the name of the variables as they appear in the estimation equations and a definition for each. The term delay in the dataset refers to the use of an extension of time, which can be granted at most of the stages of an opposition, to delay the process. During the period of the sample there were little or no restrictions on the

number of extensions of time that a party to a trade-mark opposition could use. Recent changes to the regulations by TMOB have served to reduce the unjustifiable use of extensions of time, while recognizing that extensions of time are often required for valid reasons.

The summary statistics, presented in Table III-2, show that applicants and opponents are equally likely to be successful in the trade-mark opposition process. To add more depth I provided statistics with respect to the use of extensions of time; those that are not used in estimation equations are not italicized. I find that opponents use at least one delay 45% of the time. I also note that mean size of opponents is 30% larger than the mean size of applicants, when measured in terms of revenue. That is \$13.3 billion versus \$10.2 billion in revenue. However, this is driven by the repeated participation by large firms on both sides of the opposition, as evidenced by the maximum being the same for both sides at \$408 billion.

Table III-1 Variables Used in Empirical Analysis

Variable	Definition
<i>Opp_Delay</i>	A binary dependent variable that takes on the value of 1 if the opponent uses an extension of time in the trade-mark opposition process and 0 if they do not.
<i>Opp_Win</i>	A binary dependent variable that takes on the value of 1 if the opponent is successful in the trade-mark opposition process and 0 if they are not. Success by an opponent is defined as either a decision in their favour by the trade-mark opposition board or if the applicant withdrew their trade-mark application.
<i>Size_Ratio</i>	An independent variable that measures the relative size of the two parties to an opposition. It is the ratio of the opponent revenue to the applicant revenue.
<i>Opp_Size</i>	An independent variable that measures the absolute size of the opponent in a trade-mark opposition in terms of their revenue in 2009, reported in millions of US\$
<i>Opp_Exp</i>	A independent variable that measures the experience of the opponent in a trade-mark opposition in terms of the number of oppositions they participated in between 1996 and 2009
<i>Industry</i>	A series of 19 dummy independent variables that controls for industry specific effects identified at the two-digit level of NAICS. These are presented in the Appendix
<i>Incumbent</i>	A binary independent variable that takes on the value of 1 if the opponent in the trade-mark opposition process is an incumbent and 0 if they are not. Incumbency is defined as one of the NAICS codes of the opponent matching one of the NAICS codes of the applicant.
<i>App_Size</i>	An independent variable that measures the absolute size of the applicant in a trade-mark opposition in terms of their revenue in 2009, reported in millions of US\$
<i>App_Exp</i>	An independent variable that measures the experience of the applicant in a trade-mark opposition in terms of the number of oppositions the participated in between 1996 and 2009

Table III-2 Summary Statistics

Variable	Observations	Mean or Proportion	Std. Dev. or Std. Err.	Min	Max
<i>Opp_Win</i>	2575	0.4928	0.5000	0	1
<i>Opp_Delay</i>	2575	0.4509	0.4977	0	1
<i>Size_Ratio</i>	2575	0.2847	12.292	0	618.97
<i>Opp_Size</i>	2575	13.301	36.435	0	408.2
<i>Opp_Exp</i>	2575	27.581	41.483	1	155
<i>Incumbent</i>	2575	0.3499	0.4770	0	1
<i>Industry</i>	2575	6.6670	3.1063	1	19
<i>App_Size</i>	2575	10.230	37.458	0	408.2
<i>App_Exp</i>	2575	23.460	44.089	1	176

6 Results

In this paper I use logit models where I regress the relative size (*Size_Ratio*) of the opponent to the applicant in a trade-mark opposition, the absolute size of the opponent (*Opp_Size*) and whether the opponent is an incumbent (*Incumbent*) on the likelihood that they will delay the opposition process (*Opp_Delay*) and the likelihood they will be successful (*Opp_Win*), while controlling for the size of the trade-mark

applicant (*App_Size*), the experience of both the opponent (*Opp_Exp*) and applicant (*App_Exp*) and the industry (*Industry*) of the opponent. My results show that very large companies, those with more than \$25 billion in revenues, are 6% more likely to use a delay in the opposition process and that they are 4% more likely to be successful in opposing a new trade-mark. If they are large and an incumbent they are 36% more likely to be successful in opposing a new trade-mark. This provides evidence of the strategic use of the trade-mark opposition process as a way to increase the cost of potential entrants and thereby creating barriers to entry.

With respect to the independent variables in the model, *Size_Ratio*, *Opp_Size* and *App_Size* are measured in revenue. The revenue of a firm is primarily determined by the demand for its products and the economic conditions. *Incumbent* is a random variable that is determined by the number of firms in a particular industry. It is determined by the two parties in the opposition sharing a NAICS code. I use three control variables in the models. The first is experience, *Opp_Exp* and *App_Exp*, is measured by frequency of participation in the opposition process and determined primarily by the number of years that a company has been in business. If the company has a strategy to always oppose, at some point it will have lots of experience. However, it is possible to have this strategy and have very little experience if the industry does not attract a lot of entrants or if the company has only started to adopt this strategy. Therefore, having a strategy to always oppose does not necessarily result in increased participation in oppositions. Also, 87% of the opponents in the sample are not part of the very large group that is of interest to this analysis. The third control variable, *Industry* is a set of fixed effect dummy variables for industries. The benchmark industry is the manufacturing industry,

NAICS 31-33, as this industry represents 53% of the opponents in the sample. The opponents in the manufacturing industry use at least one delay in 47.5% of the cases, slightly more often than the sample value of 45.1% of cases. The manufacturing industry wins in 47.9% of cases, slightly lower than the sample value of 49.3%. The distribution of firms across industries in the sample is determined by the relative resource endowments and the level of trade-mark usage in the industry.

The main economic mechanism that constitutes the error term is the uniqueness of the trade-mark being opposed. This should not be correlated with any of the explanatory and control variables presented above. The only candidates are *Opp_Exp* and *App_Exp*, but depending on the strategy of the company they may intentionally select very similar or very different trade-marks from those of their competitors. There should be no systematic relationship between the error term and the independent variables. The overall goodness of fit test for the logit model is a test of the relationship of the independent variables and the dependent variable. It is based on the likelihood ratios of two models and follows a chi-square distribution. The first model includes all between the independent variables while the second is an empty model. In all specifications below, the null hypothesis that there is no difference between the model as specified and a model without any independent variables is rejected.

6.1 Testing the hypotheses

To test the first hypothesis that strategically it will be the larger incumbent companies that will use delay more often in the trade-mark opposition process, I considered three specifications. In the first specification, using *Opp_Delay* as the

dependent variable, I considered the full sample. In the second specification I considered only large opponents, those with more than \$250 million (the Canadian definition for small and medium enterprises) and less than \$25 billion in revenue. The third specification considers only very large opponents; that is, those with over \$25 billion in revenue. This was chosen as a factor above how small and medium enterprises firms are defined in Canada to represent very large firms. All specifications in this section use all of the independent variables defined in Table 2. Note that heteroskedasticity is present in all estimations and robust standards errors are utilized throughout the analysis. The estimation equations take on the following forms:

Specifications 1, 2 and 3,

$$Opp_Delay = \beta_0 + \beta_1 Size_Ratio + \beta_2 Opp_Size + \beta_3 Opp_Exp + \beta_4 Incumbent + \beta_5 App_Size + \beta_6 App_Exp + \epsilon \quad (1)$$

For specification 1 through 3, I expect the coefficients for *Size_Ratio*, *Opp_Size*, *Incumbent*, *App_Size* and *App_Exp* to be positive and the coefficient for *Opp_Exp* to be negative.

Table III-3 reports the results of these regressions. In the first specification I find that the *Size_Ratio* is not statistically significant, while *Opp_Size* is positively statistically significant at the 1% level and it increases the likelihood of using at least one delay by 0.1% for every 1 billion in revenue. As opponents become very large, recall that the largest company in the sample has over \$400 billion in revenue, this impact can be quite large. *Opp_Exp* is significant at the 1% level and decreased the likelihood of the use of at least one delay. This means as companies become more experienced they are less likely to use delays. As noted earlier, increased experience does not necessarily equate strategic use in this specification. *Incumbent* is not

significant in this specification nor is *App_Size*. However, *App_Exp* is positive and significant at the 1% level; suggesting that the more experienced the applicant, the more likely it is that its opponent will use delays.

In the second specification, I consider companies that are not small or even medium sized enterprises, that is, greater than \$250 million in revenue, but are also not very large, i.e., those with over \$25 billion in revenue. I find that *Opp_Size* is not significant. *Opp_Exp* remains significant at the 1% level, suggesting that this group does learn from the experience of being in the opposition process. Again, *Size_Ratio*, *Incumbent* and *App_Size* are not significant. This is consistent with the idea that most opponents, those that are not using the process strategically, require less legitimate use of delays. *App_Exp* continues to have a positive and significant impact on the likelihood that the opponent will use delays in the process, at the 1% level.

In the third specification I limit the sample to very large opponents, i.e., those with over \$25 billion in revenue. I find that here *Size_Ratio* does matter, and is significant at the 1% level. *Opp_Size* is significant as well, at the 5% level. This is evidence that it is not only absolute size that is important, but also relative size. Of note is that the *Opp_Exp* is no longer significant. Again, *Incumbent* is not significant. This is consistent with the idea that while most opponents do not use the process strategically, very large companies do not fit this pattern and behave in a manner consistent with strategic delay. The coefficient of *App_Exp* continues to be positive and significant at the 1% level, implying that an experienced applicant increases the likelihood that an opponent will use delay in the process.

Table III-3 Opponent Delays the Process

Variable and expected sign where applicable	Opponent Uses Delays - Logit	Large Opponent Uses Delays -Logit	Very Large Opponent Uses Delays - Logit
<i>Size_Ratio</i> (+)	0.0090 (0.0125)	0.0097 (0.0024)	0.0167*** (0.0026)
<i>Opp_Size</i> (+)	0.0044*** (0.0013)	0.0014 (0.0085)	0.0038** (0.0019)
<i>Opp_Exp</i> (-)	-0.0056*** (0.0014)	-0.0047*** (0.0018)	-0.0045 (0.0043)
<i>Incumbent</i> (+)	-0.1303 (0.0950)	-0.1099 (0.1287)	-0.4074 (0.3079)
<i>App_Size</i> (+)	0.0016 (0.0011)	0.0022 (0.0015)	0.0017 (0.0027)
<i>App_Exp</i> (+)	0.0049*** (0.0013)	0.0044*** (0.0016)	0.0317*** (0.0111)
Constant	-0.1772 (0.3007)	-0.2868 (0.3147)	17.145*** (0.5588)
Wald χ^2	74.89	51.59	.
Prob> χ^2	0.0000	0.0001	.
Pseudo R ²	0.0244	0.0290	0.0661
Log pseudolikelihood	-1729.235	-1007.849	-207.605
Log pseudolikelihood constant only	-1772.405	-1043.864	-280.664
Observations	2575	1539	322
Linktest			
Predicted	1.0329*** (0.1290)	1.1148*** (0.2893)	0.8906*** (0.2453)
Predicted squared	0.0815 (0.1279)	0.0994 (0.2195)	0.2077 (0.2473)
Constant	-0.0065 (0.0472)	0.0136 (0.0791)	-0.0526 (0.1338)
LR χ^2	86.76	60.34	30.15
Prob> χ^2	0.0000	0.0000	0.0000
Pseudo R ²	0.0245	0.0291	0.0678

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

For the second hypothesis statement, that larger companies within the same industry as incumbents are more likely to win in a trade-mark opposition process, I considered four specifications. All four use the *Opp_Win* as the independent variable. As noted above this is a binary dependent variable; taking the value of one if the opponent is successful in the process and zero if they are not. The specifications in this

section include all of the explanatory variables defined above with the exception of *Size_Ratio*¹⁰. The estimation equation takes on the following form:

Specifications 4 and 5,

$$Opp_Win = \beta_0 + \beta_1 Opp_Size + \beta_2 Opp_Exp + \beta_3 Incumbent + \beta_4 App_Size + \beta_5 App_Exp + \varepsilon \quad (3)$$

In the third specification of this section I conditioned on whether the opponent was an incumbent, that is *Incumbent* = 1. The estimation equation takes on the following form:

Specification 6,

$$Opp_Win = \beta_0 + \beta_1 Opp_Size + \beta_2 Opp_Exp + \beta_3 App_Size + \beta_4 App_Exp + \varepsilon \quad (4)$$

In the fourth specification of this section I conditioned on whether the opponent was an incumbent and the applicant is a first time applicant. That is *Incumbent* = 1 and *App_Exp* = 1. The estimation equation takes on the following form:

Specification 7,

$$Opp_Win = \beta_0 + \beta_1 Opp_Size + \beta_2 Opp_Exp + \beta_4 App_Size + \varepsilon \quad (5)$$

For specifications 4 through 7 I expect the coefficients for *Opp_Size*, *Opp_Exp*, and *Incumbent* to be positive and the coefficients for *App_Size* and *App_Exp* to be negative.

Table III-4 reports the results of these regressions. In the first specification I find that the *Opp_Size* is significant at the 5% level. For a company at the minimum of the very large cutoff, \$25 billion, there is a 3.8% increase in the likelihood of being successful. For the average company in the group, at \$74.3 billion in revenue, this

¹⁰ *Size_Ratio* is an interaction term; it is the inverse of *App_Size* multiplied by *Opp_Size*. This interaction matters for identifying strategic behaviour, where the relative size gives rise to the barrier to entry problem. However, it matters less when I am interested in showing that very large firms are more likely to win.

translates into an 11.3% increase in the likelihood of success, from 49.3% to 54.8%. *Opp_Exp* is significant at the 1% level. The coefficient for *Incumbent* is negative and statistically significant at the 10% level. The result for the incumbency term indicates that being an incumbent actually reduced the likelihood of success. This is of concern and is explored in the next specification. *App_Size* is not significant, but *App_Exp* is, at the 1% level; with greater experience decreasing the likelihood of an opponent winning.

I condition on the opponent being a larger company, i.e., *Opp_Size* being more than \$25 billion in revenue. I find now that *Opp_Size* is positively significant at the 10% level; however *Opp_Exp* is no longer significant. *Incumbent* is now positive and statistically significant at the 5% level. This is evidence that small opponents are losing at a much higher rate than large opponents. This may be evidence for brand stretching, where large companies are able to move into new markets with an existing mark. The *Opp_Exp*, *App_Exp* and *App_Size* are all no longer significant. The main result here is that amongst the largest companies, being an incumbent increases the likelihood of being successful in the opposition. In fact an opponent who is very large and an incumbent is successful in the opposition process 67.2% of the time.

When I conditioned on the opponent being an incumbent I find that the *Opp_Size* is significant at the 1% level. *App_Exp* has a negative and significant impact on the likelihood of the opponent being successful, at the 10% level. *Opp_Exp* and *App_Size* are not significant. The result is that opponents who are incumbents are more likely to win if they are larger. At \$25 billion revenue, a company is 15.8% more likely to succeed. This also provides some evidence with respect to brand stretching, in that if

small incumbents attempt to block entry through the opposition process they are less likely to be successful.

When I condition on the opponent being an incumbent and the applicant being a first timer, I find again that *Opp_Size* is significant at the 1% level and the coefficient is more than twice as high as the previous model. When I consider the odds ratio a very large opponent will be successful 61.9% of the time, a 25.7% increase. *Opp_Exp* and the *App_Size* continue to not be significant. The results in this specification suggest that the size effect of opponents is largest when they are an incumbent and the entrant is a first timer.

My empirical results show that it is the size of the opponent, as measured in revenue or as a ratio of the size of the opponent and applicant, which is important in determining the use of delays in the trade-mark opposition process. The experience of both parties to the opposition process also plays a role. The larger an opponent is, the more likely they are to be successful. Moreover, opponents who are incumbents are more likely to succeed the larger that they are. This increases if the applicant is a first time participant in the trade-mark opposition process. Therefore, the concern that large firms with deep pockets may be using the trade-mark opposition process to increase costs in a specific market to deter entry is consistent with the data from the trade-mark opposition board.

It is recognized that for many of the individual results there may be alternative, plausible, explanations. Most notably, it may be the case that larger firms are more efficient and therefore are more likely to win and the data does show that when we consider all firms the experience of the firm has a significant negative impact on the

likelihood of using a delay. This would be consistent with an efficiency story. However, when we consider only the very largest firms this is no longer the case. If the efficiency hypothesis were true, the largest firms would use no delay and simply win the case as early as possible. The strategy of large firm using more delays is more consistent with the strategic hypothesis of increasing rival costs.

Table III-4 Opponent Wins

Variable and expected sign where applicable	Opponent Wins	Very Large Opponent Wins	Opponent Wins and is an Incumbent	Opponent Wins, is an Incumbent and Applicant is First Timer
<i>Opp_Size</i> (+)	0.0030** (0.0012)	0.0030* (0.0016)	0.0125*** (0.0044)	0.0206*** (0.0112)
<i>Opp_Exp</i> (+)	0.0048*** (0.0014)	0.0044 (0.0042)	-0.0008 (0.0021)	0.0003 (0.0085)
<i>Incubemnt</i> (+)	-0.1689* (0.0.935)	0.7447** (0.3057)		
<i>App_Size</i> (-)	-0.0016 (0.0012)	-0.0023 (0.0035)	-0.0054 (0.0065)	0.0052 (0.0036)
<i>App_Exp</i> (-)	-0.0058*** (0.0014)	0.0015 (0.0093)	-0.0034* (0.0019)	
Constant	-0.1195 (0.3005)	18.0066 (1.4802)	-0.5146 (0.4448)	-18.1798*** (1.1798)
Wald χ^2	60.72	.	39.27	.
Prob> χ^2	0.0000	.	0.0003	.
Pseudo R ²	0.0191	0.0609	0.0405	0.0512
Log pseudolikelihood	-1747.2011	-207.3496	-587.9051	-98.3962
Log pseudolikelihood constant only	-1784.5882	-278.6457	-620.6972	-106.5744
Observations	2570	324	889	151
Linktest				
Predicted	1.0000*** (0.1246)	0.9108*** (0.2134)	1.0265*** (0.1552)	0.9996** (0.3976)
Predicted squared	0.0345 (0.2199)	0.2724 (0.3208)	0.1591 (0.1882)	-0.0094 (0.4041)
Constant	-0.0036 (0.0461)	-0.0981 (0.1670)	-0.0343 (0.0844)	0.0022 (0.2206)
LR χ^2	68.00	32.75	50.29	10.62
Prob> χ^2	0.0000	0.0000	0.0000	0.0049
Pseudo R ²	0.0191	0.0733	0.0410	0.0512

(*p<0.10; **p<0.05; ***p<0.01. Standard errors in parenthesis)

7 Conclusion

The root of literature on the strategy to increase entrant's costs as a barrier to entry can be found in two key pieces from Dixit (1979, 1980) where he establishes that product differentiation through advertising creates inelastic demand and that the additional rent can then be expended to increase the costs of potential entrants. Previous studies on trade-marks have not addressed this behaviour directly. One study that looked at strategies with respect to trade-marks is Von Graevenitz (2007). The study focused on the strategy, a priori, to always oppose a trade-mark as a way of deterring entry. The effect of this is to increase a potential entrant's perceived cost of entry, but this is not the objective of the Von Graevenitz study. The present paper attempts to establish, empirically, that the strategy to increase the cost of entry through the trade-mark opposition process is plausible. The present paper provides answers to two key questions. First, does the size of the company or its status as an incumbent increase the likelihood it will use delays in the trade-mark opposition process? Second, does the size of the company or its status as an incumbent increase the likelihood it will be successful in the trade-mark opposition process? Alternatively, this can be thought of as asking whether very large incumbents are more likely to delay the trade-mark opposition process and whether they are more successful. If evidence for both of these questions is found in the data, then the data is consistent with the hypothesis that very large incumbents strategically use the trade-mark opposition process to increase the costs of entrants. The present study provides this evidence. I find that larger and more experienced companies are more likely to use delays in the trade-mark opposition

process. I also find that when an opposing company is an incumbent, the likelihood of successful opposition increases with size. Successful opposition also increases if the entrant is a first time participant in the process. I therefore conclude that the strategy introduced by Dixit (1980) is supported by the data, even in the presence of plausible alternative explanations of the findings in the data.

As with most studies, the precision of our answer on strategic behavior could be improved with better information. For example, what would be of particular interest is a measure for the quality of management. Since the quality of management often increases with size and is associated with previous strong profits, it would be nice to be able to separate out its independent influence. However, management quality often does not change dramatically over time nor does mismanagement always occur in smaller firms, as evinced by the 2008 financial crisis. Hence our inability to measure its contribution directly may not be a significant weakness. A similar limitation is that we cannot observe *ex ante* the quality of the trade-mark. This would allow for control of the validity of the trade-mark opposition case and therefore separate appropriate from strategic opposition.

To the extent that the trade-mark opposition process has raised entrant costs artificially, the question arises whether there are policies that can appropriately level the playing field. One potential policy could be to establish a trade-mark insurance fund, as part of the trade-mark fees collected, which could be accessed by small and medium enterprises that lack the financial resources necessary to continue in the opposition process. An additional measure would be for the loser in the process to compensate the

costs of the winner. This would act as a disincentive for very large incumbents to prolong the opposition process.

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9 Appendix

9.1 Section 30 of the Trade-marks Act of Canada

30. An applicant for the registration of a trade-mark shall file with the Registrar an application containing

(a) a statement in ordinary commercial terms of the specific wares or services in association with which the mark has been or is proposed to be used;

(b) in the case of a trade-mark that has been used in Canada, the date from which the applicant or his named predecessors in title, if any, have so used the trade-mark in association with each of the general classes of wares or services described in the application;

(c) in the case of a trade-mark that has not been used in Canada but is made known in Canada, the name of a country of the Union in which it has been used by the applicant or his named predecessors in title, if any, and the date from and the manner in which the applicant or named predecessors in title have made it known in Canada in association with each of the general classes of wares or services described in the application;

(d) in the case of a trade-mark that is the subject in or for another country of the Union of a registration or an application for registration by the applicant or the applicant's named predecessor in title on which the applicant bases the applicant's right to registration, particulars of the application or registration and, if the trade-mark has neither been used in Canada nor made known in Canada, the name of a country in which the trade-mark has been used by the applicant or the applicant's named predecessor in title, if any, in association with each of the general classes of wares or services described in the application;

(e) in the case of a proposed trade-mark, a statement that the applicant, by itself or through a licensee, or by itself and through a licensee, intends to use the trade-mark in Canada;

(f) in the case of a certification mark, particulars of the defined standard that the use of the mark is intended to indicate and a statement that the applicant is not engaged in the manufacture, sale, leasing or hiring of wares or the performance of services such as those in association with which the certification mark is used;

(g) the address of the applicant's principal office or place of business in Canada, if any, and if the applicant has no office or place of business in Canada, the address of his principal office or place of business abroad and the name and address in Canada of a person or company to whom any notice in respect of the application or registration may be sent, and on whom service of any proceedings in respect of the application or registration may be given or served with the same effect as if they had been given to or served on the applicant or registrant himself;

(h) unless the application is for the registration only of a word or words not depicted in a special form, a drawing of the trade-mark and such number of accurate representations of the trade-mark as may be prescribed; and

(i) a statement that the applicant is satisfied that he is entitled to use the trade-mark in Canada in association with the wares or services described in the application.

9.2 Collinearity diagnostics

The measures in the diagnostic test output are measures of the strength of the interrelationships among the variables. The first two measures are the variance inflation factor (VIF) measures and reflect how much of the increase in the standard error could be caused by collinearity. The second two are known as tolerance measures, and are indicative of much collinearity can be present before it becomes a problem. The tolerance for a given variable is equal to 1 minus the R^2 that results from the regression of the other independent variables on the variable in question. The corresponding VIF is simply the inverse of the tolerance. If all of the independent variables are orthogonal to each other the VIF and tolerance are equal to 1. Collinearity is deemed to be present when the VIF is near 5. The results indicate that collinearity is not an issue between the independent variables.

Table III-5 Collinearity Test of Explanatory and Control Variables

Variable	Variance Inflation	Variance Inflation Squared	R – Tolerance	R – Tolerance Squared
<i>Size_Ratio</i>	1.00	1.00	0.9984	0.0016
<i>Opp_Size</i>	1.24	1.11	0.8072	0.1928
<i>Opp_Exp</i>	1.98	1.41	0.5059	0.4941
<i>Incumbent</i>	1.38	1.18	0.7236	0.2764
<i>Industry</i>	1.06	1.03	0.9457	0.0543
<i>App_Size</i>	1.02	1.01	0.9777	0.0223
<i>App_Exp</i>	1.96	1.40	0.5093	0.4907
Mean VIF	1.35			

9.3 NAICS codes used as fixed effects

1. Manufacturing 31-33
2. Agriculture, Forestry, Fishing and Hunting 11
3. Mining 21
4. Utilities 22
5. Construction 23
6. Wholesale Trade 42
7. Retail Trade 44-45
8. Transportation and Warehousing 48-49
9. Information 51
10. Finance and Insurance 52
11. Real Estate Rental and Leasing 53
12. Professional, Scientific, and Technical Services 54
13. Management of Companies and Enterprises 55
14. Administrative & Support and Waste Management & Remediation Services 56
15. Educational Services 61
16. Health Care and Social Assistance 62
17. Arts, Entertainment, and Recreation 71
18. Accommodation and Food Services 72
19. Other Services (except Public Administration) 81
20. Public Administration 92