Innovation, Fast Seconds, and Patent Policy

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Abstract

We develop a model of innovation in which entrepreneurs develop a new (differentiated) product market that is subsequently exploited by a well-established firm that “stretches” its brand to enter the new market as “fast second”. In this setting, there is a positive externality to the pioneering efforts of the initial entrants that may well increase with the number of such entrants. We develop a model that exhibits this externality and use it to evaluate the design of patent policy—specifically patent breadth—with a view to encouraging the optimal amount of initial entry.

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1. Innovative Entrepreneurs and “Fast Second” Movers

This paper explores the dynamics of product innovation and market evolution and the role of patent policy to insure that this process yields maximum social benefits. Industrial economists have been concerned about the processes underlying the evolution of industrial structure at least since the work of Gibrat (1931) and Schumpeter (1942). Over time, this has led to a gradual recognition of the critical role played by entrepreneurial startups in bringing basic inventions to the market in the form of new, innovative applications. [See, for example, Kortum and Lerner (2000).] Yet if established firms are not always the originators of new product markets, they often still play an equally critical role in building on the experiences of the initial startups and then entering with a version of the product that consumers prefer. In this “fast second” policy, emphasized by Markides and Geroski (2005), the commercial advantages of large, established firms allow them to emerge often as the dominant design or even as the standard for the industry despite their late entry. Procter & Gamble for instance, was more than a decade behind the initial introduction of disposable diapers, with a number of firms marketing such a product by the time that P&G finally launched their “Pampers” diaper in 1964. Yet by 1968, P&G’s market share was well over 90 percent. Markides and Geroski (2005) show that this example can be multiplied many times over. In fact, it is now clear that such “fast second” tactics are an explicit component of corporate strategy. Schnars (1994) quotes a Coca-Cola manager giving dramatic testimony in support of this strategy: “We let others come out, stand back and watch, and then see what it takes to take the category over.”

The later entry of large, established firms as “fast seconds” is likely an important reason that a large proportion of the many small new firms that start each year typically exit within a short time. The well-known manufacturing study of Dunne, Roberts, and Samuelson (1988) and the
more recent survey of retailing entry by Jarmin, Klimek, and Miranda (2004) both find that over 60 percent of new firms exit within five years of entry and 80 percent leave within ten years. Of course, such exit can be accomplished by selling out to another firm rather than simple failure. Cummings and Macintosh (2003) and Cochrane (2005) present evidence that from 1987 to 2000 about 20% of venture backed firms were acquired. Most of the leading textbooks in Entrepreneurship, for example Barringer and Ireland (2008) advocate selling to a major established firm as a possible entrepreneurial exit strategy. However, whether a fast second’s entry is accomplished by acquiring initial entrants or simply leads to their exit, it seems clear that such entry will have a major impact on the market environment when it occurs.

In short, a common pattern of industrial evolution is one in which a first generation of small, pioneering firms serves to establish a market that is later targeted for entry by large, established firms. Viewed in this light, the innovation process is analogous to an ecological food chain in which a thriving population of little fish provides important nutrients for the larger “big fish”. In turn, these fast second big fish provide nontrivial product enhancements to final consumers. In both systems, there is a danger that the big fish or fast second firms will over-harvest and leave too few little fish, thereby threatening the health of the entire system.

In this paper, we build on our earlier work to develop a model of market evolution that incorporates this “big fish-little fish” analogy. We show that concerns about “overfishing” by the fast second firm are well-founded. We then explore the role of patents in enhancing the performance and sustainability of this dynamic market environment.

Specifically, we explore the evolution of market structure and the associated welfare implications in a differentiated product market when initial startups create a new market but do so in anticipation of later entry by a large fast second offering a competing product that consumers value more highly. In this model, there is an externality between initial entrants and
the gains provided by the fast second with the result that unconstrained market processes will typically fail to maximize the total surplus. In particular, the fact that the initial startups anticipate the fast second’s later entry and the implications that has for their survival typically result in too little entry in the first place. We then explore the ability of patent policy, particularly patent breadth, to address this market failure. We find that somewhat broad patents that cover a wider variety of product types may actually induce more entry than would otherwise occur and thereby raise social welfare. However, we also find that achieving a first-best solution via patent policy is often impossible and that this difficulty is greater in markets where consumers have weaker attachments to their most preferred version of the product.

Our basic model of initial entry and survival after the emergence of a fast second is presented in the next section for both a market without patents and one in which early entrants can patent their products. We then consider optimal patent and patent breadth policy in Section 3. A summary and concluding remarks follow in Section 4.

2. A Big Fish, Little Fish Model of Innovation and Market Evolution

2.1 Opening the Market

We consider a technological breakthrough whose commercialization leads a number of startup firms to open a new differentiated product market. The assumption of product differentiation makes sense for product innovation in “high tech” sectors such as information technology, biotechnology, aerospace, nanotechnology and robotics.

Product differentiation in our analysis is represented by the “Salop circle”, a one-dimensional circular space Λ whose length is normalized to unity. Consumer preferences for new products are assumed to be uniformly distributed over the circle. The “location” of consumer s defines that consumer’s most preferred technology or specification for a new product
in this market. For each consumer \( s \), the surplus obtained from buying the new product with specifications \( x \) at price \( p(x) \) is:

\[
U(x,s) = V - p(x) - t|x - s|
\]  

(1)

Here, \( V \) is the consumer’s reservation price and \( t \) is the loss of utility per unit “distance” that the consumer incurs in buying a product other than her most preferred technology. Each consumer buys exactly one unit of the product.

When a little fish or innovator commercializes the new technology it incurs a sunk cost \( F \) and locates on the circle. We assume that marginal costs for all firms are constant and so can be normalized to zero without loss of generality. The “location” \( x_i \) of innovative firm \( i \) is the specification of its basic application of the new technology. Relocation of the basic application is assumed to be prohibitively costly, but the innovator can adapt its basic application by incurring versioning costs that allow the firm to offer a line of new products designed specifically to meet the most preferred specifications of its potential consumers. Versioning by innovator \( i \) of the basic technology \( x_i \) to the product specification \( x \) incurs the cost:

\[
MC_i(x_i,x) = r|x_i - x|
\]  

(2)

The versioning technology has two essential features. First, it is perfect in the sense that a consumer is indifferent between the product \( s \) and a basic product \( x_i \) versioned to \( s \) if these two products are offered at the same price. Second, because we assume that the versioning cost \( r < t \) the early innovators have a profit incentive to version their products to the preferences of each consumer they serve in the new market. As a consequence, an important property of versioning (Norman and Thisse, 1999) is that it forces our innovative firms to adopt discriminatory prices. To see why, suppose, by contrast, that firm \( i \) adopts non-discriminatory (fob) pricing. Versioning gives a firm control of “delivery” of its product to consumers. As a result, a neighboring firm \( j \) can offer a versioned product that is priced to undercut firm \( i \) at any of firm \( i \)’s consumer
locations such that firm \( i \)'s delivered price is greater than firm \( j \)'s production plus versioning costs. Hence, no commitment to adopt non-discriminatory pricing is sustainable. Rather, offering versioned products at discriminatory prices emerges as a dominant strategy for all firms.

Competition in the new market is modeled as a four-stage, two-period game. We contrast two versions of this competition. In the first version there is no patent regime. In the second, each innovative pioneer \( i \) secures a patent of width \( w_p \) that gives firm \( i \) the exclusive right to produce versioned products within an arc of length \( w_p/2 \) on either side of its base product \( x_i \).

In both versions, in the first stage and first period a set of identical, risk-neutral innovative firms – little fish – choose whether or not to enter the market by spending on research and development. In the second stage of this first period these firms then compete in prices. In the third stage that marks the start of the second period the market grows – perhaps as the commercialized products become more familiar to and popular with consumers – with consumer density increasing from \( d_0 \) in the first-period to \( \delta d_0 \) in the second (\( \delta > 1 \)). At the same time a fast-second or big fish chooses whether or not to enter the market. It will do so if, because of its brand name or other advantages, it can offer a product that consumers consider superior to those offered by the original firms.

If there is no patent regime in place, entry by the fast second is uninhibited. It can locate anywhere on the circle and proceed to compete against the innovative pioneers as it wishes. By contrast, if there is a patent regime in place the fast-second can only enter by buying the patents of early pioneers. In this case, it enters by making a take-it or leave-it offer to purchase the patents of a subset of the little fish. In either case, given that entry by the fast-second is successful, in the final stage the fast-second markets its branded product or service. The fourth and final stage then proceeds as the last part of period two with all remaining firms, including the fast second, competing in prices.
We solve for the perfect equilibrium to this game. This implies that the innovative firms, in making their entry decisions in stage 1, correctly anticipate market growth, the price competition outcome in stage 2, the possibility of fast-second entry in stage 3, and the post-entry price competition and equilibrium of stage 4. All firms have a unit discount factor.

We consider first the case in which there is no patent protection, which we have discussed extensively in an earlier paper [Norman, Pepall and Richards (2008), designated NPR hereafter]. Let the number of initial innovators or little fish in any period be \( n \). Then for these \( n \) firms, standard analysis (Eaton and Schmitt, 1994) gives the Bertrand-Nash equilibrium set of prices generated by competition in either period as:

\[
p_i^{np}(s) = \min \left( V, \max \left( r_i - s, \min_{j \neq i} r_j - s \right) \right) \quad \forall i = 1, \ldots, n
\]

Note that each innovator’s price cost margin is monotonically increasing in \( r \). In other words, the versioning cost parameter \( r \) serves as a proxy measure for the intensity of price competition. As \( r \) increases, price competition becomes less intense in the new market.

The bold line in Figure 1 illustrates the pre-fast second equilibrium.

![Figure 1: Price Equilibrium with \( n \) Innovative Entrants – No Patent Regime](image-url)
Price competition forces the price at each consumer location to the costs of the innovator whose basic application is second nearest to that location. If there are \( n \) innovators symmetrically located along the circle, each having developed the basic application at their location, then the market share of each is \( w = 1/n \) and the first-period profit, ignoring sunk costs of commercializing the technology, is:

\[
\pi_{np} = \frac{d_0 r}{2 \pi n^2} \tag{4}
\]

Now consider the pre-fast second market equilibrium with patents. Assume that the patent authority awards each innovative entrant a patent of radius \( w_p/2 \) centered on its basic product where \( w_p/2 \) is sufficiently wide to allow the innovative entrants to at least break even. There will now be \( n_p = 1/w_p \) innovative entrants. More critically, the patent regime changes the nature of the price competition and hence, the equilibrium Bertrand-Nash prices. This is illustrated in Figure 2.

Consider a representative consumer distance \( s < w_p/2 \) from innovative firm \( i \). Firm \( i + 1 \) can no longer offer this consumer a product perfectly customized to \( s \) since that would result in an infringement of firm \( i \)’s patent. The best that firm \( i + 1 \) can offer to a consumer at \( s \) is the product customized to the boundary between firm \( i + 1 \) and firm \( i \). In order to purchase this product the consumers at \( s \) have to “travel” a distance \( w_p/2 - s \), incurring costs \( t(w_p/2 - s) \). As a result, the Bertrand-Nash equilibrium set of prices under the patent regime for any consumer distance \( s < w_p/2 \) from firm \( i \) is:

\[
p^p_i(s) = \min \left( V, \max \left( r|x_i - s|, \min_{j \neq i} \frac{r w_p}{2} + t \left|x_j - \frac{w_p}{2} - s\right| \right) \right) \quad \forall \ i = 1,\ldots,n \tag{5}
\]

This is illustrated by the bold line in Figure 2.

\(^2\)Our approach is similar to Klemperer (1990). Important differences between our approaches are: 1) Klemperer’s consumers all agree on the most preferred product whereas our consumers have heterogeneous preferences over product types; 2) Klemperer has one patent whereas we allow for multiple patents; and 3) Klemperer’s consumers have heterogeneous taste parameters \( t \) whereas our consumers have identical taste parameters.
Now the price to each consumer location equals the cost incurred by the innovator with the second-nearest basic application in providing the closest versioned product that the patents allow plus the utility cost to the consumer from purchasing a product that is not that consumer’s most preferred product. In short, prices are generally higher under the patent regime.

The first-period profit of an innovative entrant, again ignoring the sunk costs of commercializing the technology, is now:

$$\pi_p = d_0 (r + t) w_p^2 / 4 = d_0 (r + t) / 4 n_p^2$$

(6)

It is useful to compare an initial entrant’s first-period profit under a no-patent and with-patent regime for the case in which $w = w_p$, i.e., for the case in which patents are designed to yield the same number of entrants as would occur in a totally free market. Comparison of (4) and (6) indicates that the patent regime increases the first-period profits of the innovative entrants just as intuition suggests because the patents restrain price competition. A firm’s ability to compete beyond its patent boundary now depends on the consumer taste parameter $t$. In the patent-regime case, $t$ plays a role similar to $r$ in that price competition intensifies as $t$ declines. However, since $t > r$, such extra-territorial competition must be less intense under the with-patent than it is under the no-patent case. It follows that the additional profits generated by the patent

Figure 2: Price Equilibrium with $n$ Innovative Entrants – Patent Regime
regime rise as $t$ increases. In other words, the protection afforded by the patent regime is more valuable to firms when consumer tastes are more intense. This link between the profit-impact of patents and the taste parameter $t$ is a unique feature of our analysis.

2.2 Fast Second Entry and Innovative Survival

Innovation by “little fish” reveals information about the new market to potentially bigger predators. From the perspective of the big fish, this is an important and key role played by start-up firms. A big fish, firm $b$ is by assumption a well-established firm in another market. As such, we assume that it has the ability either to make a product or service improvement or leverage its brand strength in a manner that gives it an advantage relative to the pioneer innovators. The result is that consumers are willing to pay more for firm $b$’s new products than for those developed by the original innovative firms.

As in NPR, we capture the information externality and the advantage of big fish firms as follows. We assume that there is a population of established firms, each characterized by a parameter $\alpha$ uniformly distributed between 0 and 1. Nature randomly selects one of these firms and that firm, having a specific value of $\alpha$, decides whether to enter the new market. If the big fish enters we assume that it operates the same customizing technology as the innovative entrants. A technical assumption that we make throughout the analysis (see NPR) is:

Assumption r: $r \leq 1$.

The effect of this assumption is that if the fast-second has maximal brand strength $\alpha = 1$ it is able to monopolize the market in the absence of patent protection.

At the time of the fast second’s entry (the beginning of period 2 in our analysis), there are $n$ innovative entrants, symmetrically located on the circle, each with a market share of $1/n$. The expertise and advantage that the fast second firm brings to the new market is captured by assuming that consumers are willing to pay $\alpha - 1/n$ more for its product than they are willing to
pay for a substitute product with the same characteristics offered by a pioneering (small fish) firm.³ This assumption captures the idea that the market experience of the little fish provides information to the big fish, and that more little fish means more valuable information. By contrast, if there are “very few” innovators at the end of the first period, it is more likely that the randomly selected fast second will not have a sufficiently large \(\alpha\) value to make entry profitable.

Uncertain survival is a fact of life for startups. That uncertainty is reflected here in two ways. First, whether the fast second will enter is probabilistic owing to Nature’s random selection of the \(\alpha\) value. Second, when the big fish does come in, its location along the circle is uncertain. The big fish can choose to locate on or buy out any one of the little fish with equal probability. In addition, the impact of the fast second’s entry on prices and profits of an innovative entrant will be much greater if that entrant is nearer the fast second’s point of entry than if it is farther away.

To be precise, an innovator \(j\) faces three possible outcomes in the wake of \(b\)’s entry. One is that nothing changes, which happens if there is at least one surviving innovator in both directions between \(j\) and \(b\). Price discrimination via versioning localizes all competition with the result that the two firms \(j\) and \(b\) do not compete for customers in this case. The second possible outcome is that competition with \(b\) is so intense that firm \(j\) exits. The final possibility is that all the early innovators between \(j\) and \(b\) exit so that \(j\) becomes either the left-or right-hand survivor that directly competes with \(b\). In this case, for the innovator \(j\) to survive it must be able profitably to undercut the big firm’s superior brand offering in some part of its market area. However, the probability that an innovative entrant will survive fast-second entry in the second period is also affected by whether or not there is a patent regime. We therefore examine the with-patent and no-patent case in turn.

³ Pepall and Richards (2002) and NPR provide an extensive discussion of the reasonableness of this assumption.
Case 1: Entry and Survival in a No-Patent Regime

Suppose first that there are no patents. The fast-second big fish can enter wherever it likes. Its brand advantage $\alpha - 1/n$, location, and the intensity of price competition $r$ will then combine to determine whether or not a particular pioneer survives. Suppose without loss of generality that the fast-second chooses to locate on innovative entrant 0. Such entry is feasible if and only if the fast-second’s brand strength $\alpha$ is at least $1/n$. In this case, the two nearest neighbors, 1 and $n-1$, to the fast-second point of entry will survive if and only if the brand-stretcher is unable to undercut them at their base product locations, which requires that $\alpha < 1/n + r/n$. The second-nearest neighbors, 2 and $n-2$, to the fast-second survive if and only if $\alpha < 1/n + 2r/n$ and so on.

The bold line in Figure 3 illustrates the impact of firm $b$ entering the market at position 0, with firms numbered counter clockwise. Early innovators 1 and 2 exit the market because the discount $\alpha - 1/n$ that they must offer to retain even their most proximate consumers is so great that they have to sell at a loss.

![Figure 3: Fast-Second Entry and Innovative Survival – No Patent Regime](image-url)
Suppose that \( n \) is odd, with \( n = 2m + 1 \). Our analysis in NPR indicates that the number of innovative entrants to survive the fast-second’s entry is

\[
s_{np}(n,r) = n \int_{0}^{\frac{1}{n}} d\alpha + \sum_{j=1}^{m} \left( 2m + 2 - 2j \right) \int_{\frac{1}{n} \cdot \left( \frac{j}{n} \right)}^{\frac{1}{n}} \frac{1}{n} d\alpha = 1 + \frac{(n^2 - 1)r}{4n}
\]

(7)

The related probability of an innovative entrant surviving fast-second entry is:

\[
\rho_{np}(n,r) = \frac{s_{np}(n,r)}{n}
\]

(8)

Note that the probability of survival is independent of market size or growth. It is totally determined by the ability of a small fish to survive price competition with the big fish. The probability of survival is, however, increasing in versioning costs \( r \). Put another way, an innovative entrant is more likely to survive fast-second entry if price competition is less intense. The probability of survival is also increasing in market share \( w = 1/n \), reflecting our assumption that the information gains and the fast-second advantage they imply are weaker the fewer initial innovators that there are.

From (8) and (4) the expected profit of an innovative entrant in the absence of a patent regime is:

\[
\pi_{np}(\delta, n, r, F) = \frac{d_{r}r}{2n^2} \left( 1 + \delta \rho_{np}(n,r) \right) - F = \frac{d_{r}r}{8n^3} \left( \frac{1}{n} \right) \left( 4 + \frac{r \delta}{4n^4} \right) + 4n \delta - r \delta - F
\]

(9)

Define \( f = F/d_0 \) where \( f \) is a per-capita set-up cost. Innovative firms enter in the first period so long as they expect to at least break even over the two periods of the market, given that they correctly anticipate fast-second entry in period 2 and the outcome of price competition in periods 1 and 2. Equation (9) therefore permits us to identify the equilibrium number of pioneer firms:

\[
n_{np}^*(\delta, r, f) = n : \frac{r}{8n^3} \left( 4 + \frac{r \delta}{4n^4} \right) + 4n \delta - r \delta - f = 0
\]

(10)

\(^4\)In NPR we treat both \( n \) odd and even. As the outcome is identical in all material aspects, we assume \( n \) odd here to facilitate analytical calculations. In fact, it can be shown that no generality is lost by ignoring integer constraints on \( n \).
It is easy to confirm that \( \partial n_{np}(\delta, r, f)/\partial \delta > 0; \partial n_{np}^*(\delta, r, f)/\partial r > 0; \partial n_{np}^*(\delta, r, f)/\partial f < 0 \). We can expect to see more innovative entry in markets that are expected to grow more quickly; in markets where price competition as proxied by \( r \) is less intense; and in markets where the per-capita set-up costs are lower.

**Case 2: Entry and Survival in a With-Patent Regime**

Now assume that there is a patent regime as defined above where each initial entrant has a patent to supply customers within the arc length \( w_p/2 \) of its base product. First, it is obvious that for entry of the fast-second big fish to be feasible, firm \( b \) must purchase the patent of at least one innovative entrant. We assume non-cooperative behavior among the initial entrants so that there is no for them to act as a coalition and jointly refuse to sell any patent/location to firm \( b \).

Second, we assume that if \( b \) purchases one or more innovative entrant’s patent, \( b \) will produce these entrants’ products by versioning its own base product rather than by offering multiple base products. In other words, the fast second purchases the right to offer these versioned products but does so using production facilities that are associated with its established brand. An obvious justification for this assumption is to suggest that if, to the contrary, the fast-second offers multiple base products – the base products of all the innovative entrants that it purchases – it dissipates its brand strength, undermining its ability to enter in the first place.\(^5\)

This leaves the question of the price the fast second pays to acquire an initial entrant’s patent. We assume that each initial entrant establishes a reservation price at which it is willing to sell its patent based on its expected second-period profit, accounting for the probabilistic nature of both the fast second’s brand advantage and entry location. In making this calculation, we assume that an innovative entrant, in calculating its probability of survival given that it is the \( j \)th nearest neighbor to the fast-second, assumes that the fast-second has purchased the patents of its

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\(^5\) Note that if it were sensible for the fast second to produce at multiple locations, the problem would become trivial as it would simply buy all initial entrants’ patents.
(j – 1) nearest neighbors. We can then calculate the number of innovative entrants that is likely to survive entry of the big fish with its stronger brand and the probability that each such innovative entrant will survive in period 2.

For example, assume that the brand-stretcher enters by purchasing the patent of firm 0. To do so it must have brand strength of at least $w_p = 1/n_p$. For the two nearest neighbors, 1 and $n-1$, to survive it must be that the fast-second is unable to undercut its nearest neighbor 1 in supplying that nearest neighbor's left-most consumer, given that this consumer has to travel to firm 1's rightmost boundary in order to purchase the fast-second's customized product. The lowest price that this consumer incurs in buying from the fast-second is $rw_p/2 + tw_p$ while the price paid to firm 1 is $rw_p/2$. So we require $\alpha - w_p < tw_p$. Similarly, for the second-nearest neighbors 2 and $n-2$ to survive the lowest price that the consumer incurs in buying from the fast second is $3rw_p/2 + tw_p$ while the price paid to firm 2 is $rw_p/2$. So we require $\alpha - w_p < tw_p + rw_p$. For the third-nearest neighbors 3 and $n-3$ to survive we have the same argument again. The lowest price that the consumer incurs in buying from the fast second is $5rw_p/2 + tw_p$ while the price paid to firm 3 is $rw_p/2$. So we require $\alpha - w_p < tw_p + 2rw_p$.

We can extend the above argument repeatedly throughout the $2m_p$ initial firms on either side of the fast second’s point of entry/base of operations, on the assumption that the initial number of innovative entrants $n_p = 1/w_p$ is odd and equal to $2m_p + 1$. Given the distribution of the fast-second’s brand advantage $\alpha$, this allows each entrant to determine the likely number of survivors in the wake of a fast second’s entry. This is:

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6 We can always number the innovative entrants such that this is the case.
7 Since we ignore integer constraints on $n$ in our formal analysis no generality is lost in assuming $n$ is odd in calculating the probability of survival.
\[ s_p(n_p, r, t) = \int_0^{1/n_p} n_p d\alpha + \int_{1/n_p}^{(1+1)/n_p} 2m_p d\alpha + \sum_{j=2}^{m_p} \left(2m_p + 2 - 2j\right) \int_{(1+1/jr)/n_p}^{(1+1/jr)/n_p} d\alpha \]
\[ = 1 + \frac{(n_p - 1)((n_p - 3)r + 4t)}{4n_p} \]

If follows that the probability of an innovative entrant surviving fast-second entry is:

\[ \rho_p(n_p, r, t) = s_p(n_p, r, t)/n_p \] (12)

Given equations (12) and (6), each initial entrant can work out its expected profit for the second period \( E(\pi_p^2) \). This is the reservation price at which each will sell its patent: the entrant will earn this profit, on average, whether or not it actually sells its patent. Knowing this price, we envision that the fast second enters at the start of the second period by announcing an auction for the patent rights of initial entrants. The auction clears at price \( E(\pi_p^2) \) at which price the fast second buys \( 2k + 1 \leq 2m_p + 1 \) patents. It is then straightforward to show that for an innovator or pioneering entrant, the total expected profit over both periods 1 and 2 of the model is:

\[ \pi_p(\delta, n_p, r, t, F) = \frac{d_0(t + r)}{4n_p^2} \left(1 + \delta \rho_p(n_p, r, t)\right) - F \]
\[ = \frac{d_0(t + r)}{16n_p^4} \left(n_p^2(4 + r\delta) + 4n_p \delta(1 + t - r) - (4t - 3r)\delta\right) - F \] (13)

Note that unlike the no-patent regime case, the number of innovative entrants with patent rights is fully determined by the patent office provided only that (13) is non-negative. From this, it is easy to confirm that the probability of survival and also the expected profit of an innovative entrant are increasing in \( w_p, r \) and \( t \). The patent regime protects innovative entrants from fast-second entry in two ways. First, to the extent that \( w < w_p \), the fast-second needs a greater brand advantage for its entry to be feasible since it must be the case that \( \alpha > w \) for fast second entry in

\[ ^8 \text{In the case of } r \text{ provided that } w_p < 1/3 \text{ or } n_p > 3. \]
the no-patent case, while we must have $\alpha > \omega_p$ for fast second entry in the with-patents case. An increase in patent breadth makes this entry condition tougher and acts like a structural barrier to entry. Second, the patent regime protects each innovative entrant from the need to compete directly with the products of the fast-second. This protection is stronger in markets where consumer tastes, as measured by the parameter $t$, are more intense.

3. Optimal Patent Design in a Big Fish, Little Fish Model

The question to which we now turn is whether the patent regime can be designed to secure the socially optimal level of innovative entry in our Big Fish, Little Fish scenario. As a starting point consider our spatial market on the assumption that there is no fast-second entry. The aggregate profit of each innovative firm is:

$$\pi_{np}^f(n) = \frac{d_0r(1+\delta)}{2n^2} - F$$

As a result, the free-entry number of innovative firms is:

$$n_{e}^f = \sqrt{\frac{d_0r(1+\delta)}{2F}}$$

(15)

The social optimum in this setting is the number of innovative entrants $n_0$ that minimizes total production, plus versioning plus set-up costs. These costs are:

$$TC_{nf}^f(n) = \frac{d_0r(1+\delta)}{4n} + nF$$

(16)

Accordingly, the socially optimal number of innovative entrants is:

$$n_0 = \sqrt{\frac{d_0r(1+\delta)}{4F}}$$

(17)

Equation (17) has a well-known implication common to models based on the Salop circle model of product differentiation, namely, excessive entry. [See, e.g., Tirole (1988)]. In the absence of a fast-second and with no patent regime, there will be excessive innovative entry.
The introduction of a patent regime in a world without the threat of fast second entry thus raises the possibility that it may correct market failure by constraining entry to the socially optimal value.

With the introduction of a patent regime the profit of an innovative entrant is, from (6):

$$\pi_p(n_p) = \frac{d_o(t + r)(1 + \delta)}{4n_p^2} - F$$

Since every consumer is supplied with a customized product, the social optimum (17) does not change. As a result, the program confronting the patent office is:

$$\min_{n_p} TC_p(n_p) \text{ subject to } \pi_p(n_p) \geq 0$$ (18)

Designing the patent regime is straightforward. The social planner sets the patent width at $w_0 = 1/n_0$ and the non-negative profit constraint is not binding.

Proposition 1: If there is no threat of fast-second entry the optimal patent width is

$$w_0 = \frac{4f}{\sqrt{r(1 + \delta)}}. \text{ Each innovative entrant earns excess profit } tF/r \text{ and the patent system generates the first-best level of innovative entry.}$$

Optimal patent width is greater when set-up costs are high, versioning costs are low, and market growth is low. The intuition is simple to see. In the absence of a patent regime (and the threat of a fast-second) we have seen that there is always excess entry so the patent system needs to restrict entry. If set-up costs are high and/or versioning costs are low the patent system needs to be more restrictive in order to reduce total costs.

Note also that while the consumer taste parameter $t$ does not affect optimal patent width, it does affect the benefits that firms derive from the patent regime. Excess profit is greater in markets where consumer tastes are more intense.
Now return to our analysis with fast-second entry. This introduces a complication to the calculation of the social optimum in that we must allow for the fact that consumers place additional value on the fast-second’s products. The socially optimal number of innovative entrants is that which minimizes total versioning plus set-up costs – including those of the fast-second in period 2 – minus the additional expected surplus created by the fast second. NPR refer to this as expected net cost, which we denote $ENC(n)$, where $n$ is the number of innovative entrants.

Assume that, in common with consumers, the social planner does not know the brand-strength of the fast-second. NPR show that the socially optimal number of innovative entrants $n_0$ solves:

$$n_0 = n : \frac{3n^2(16\delta - 4r(\delta - 1) + r\delta^2) - 4n(12 - 6r + r^2) + 3r^2\delta}{48n^4} - f = 0$$

(19)

NPR then demonstrate that: “The equilibrium number of early entrants is always less than the socially optimal number.... (T)he degree to which there is insufficient early entry decreases as versioning costs $r$ rise; as set-up costs $F/d_0$ rise; and as market growth $\delta$ falls.

The threat of fast-second entry complicates the task of setting patent width. Admittedly, as we have seen, the introduction of a patent regime increases the expected profits of each innovative pioneer. This tends to undo the disincentive on initial entry that the fast second’s later entry creates. However, when $t$ is sufficiently low, it is still possible that even when the patent width is set at a level that would yield optimal entry in the absence of the fast-second threat, the fact that the threat is real implies that initial entrants still expect to lose money. There are two forces behind this result. First, when $t$ is low, first-period profits are low because the ability of the initial entrants to charge high prices to infra-marginal consumers is more limited as

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9 Again we ignore integer constraints.
shown by equation (6). Second, when \( t \) is sufficiently low, the fast-second’s brand advantage allows it to compete successfully against even those pioneer firms whose product types are well beyond the fast second’s own acquired patent rights. When consumers are not strongly wedded to their most preferred brand, they are willing to travel some distance to acquire the fast-second’s preferred product.

The constrained optimization facing the patent office is now

\[
\min_n ENC(n) \text{ subject to } \pi_n(\delta, n, r, t, F) \geq 0
\]

(20)

If the non-negative profit constraint is non-binding then \( n_0 \) is determined from (19) whereas if it is binding it is determined from (17).

We have already seen that the expected profits of the innovative entrants are increasing in the consumer taste parameter \( t \). A convenient way to determine the circumstances under which the patent regime can give the first-best social optimum, therefore, is to identify the critical value of \( t \) above which the non-negative profit constraint in (17) is not binding. This is illustrated in Figure 4.

We can conclude:

Proposition 2: If there is the threat of fast-second entry the critical value of the consumer taste parameter \( t \) above which the patent regime generates the first-best social optimum is decreasing in set-up costs \( f \); decreasing in versioning costs \( r \) and increasing in the market growth rate \( \delta \).

We can put this another way. If the patent system is to satisfy the non-negative profit constraint it has to depart from the social optimum to a greater extent in markets where set-up costs are low, versioning costs are low, the growth rate is high and consumer tastes are less intense.
The intuition underlying this result is clear. In deriving the socially optimal level of innovative entry the social planner recognizes the value of the additional surplus that the fast-second brings to the market. Broader patents limit the likelihood of these gains by making it more difficult for the fast second to enter and compete. However, when a pioneer firm’s expected profit is negative over a large part of the parameter space, broader patents are necessary to get any initial entry at all.

![Figure 4: Critical Consumer Taste Parameter t](image_url)

As shown above, the expected total profit of an initial entrant is increasing in \( w_p \), \( r \) and \( t \) but decreasing in \( f \). Therefore, when \( w_p \), \( r \) and \( t \) are large and/or \( f \) is small, the difference between
the free-entry number of innovative entrants and the socially optimal number is also small and it
is more likely that the additional profits generated by the patent regime can attain the first-best
social optimum. By contrast, when the opposite market conditions apply, the free-entry
equilibrium contains many fewer innovative entrants than the social optimum. In this case, the
patent regime may still be able to achieve the social optimum based on the additional profits it
generates, but to do so requires that consumer tastes are “very intense”. It is more likely in these
circumstances that the patent-office will have to settle for a second-best outcome in which
patents are broader than would otherwise be the case. Somewhat paradoxically, these broader
patents may actually encourage more entry than narrower ones.

4. Conclusion

   It has long been recognized that innovative start-up companies play a critical role in market
evolution and in the commercialization of basic research. At the same time, a common feature in
many markets is that many innovative entrants are subsequently replaced by established firms.
Indeed, these later entrants have the capability to leverage their established brands into new
markets to such an extent that they often come to dominate these markets even though they are
late arrivals.

   In this paper we have developed a “big fish, little fish” analogy to provide insights into this
kind of market evolution. Our analysis brings together in a novel approach the key facets of
innovation, intellectual property rights and competition policy. Our approach to innovation,
based on the familiar Salop model of horizontal product differentiation, allows us to identify and
clarify a number of the issues that arise in determining optimal patent breadth. Moreover, we are
able to investigate how optimal patent design varies with the structural features of markets, such
as the extent of sunk costs for product development, potential market size, the intensity of
competition and the intensity of consumer tastes.
A key feature of our “big fish, little fish” model of innovation that underpins and motivates the analysis is the information externality that early entrepreneurs provide to late-entering but brand-advantaged firms. As in most ecosystems, our model exhibits a delicate balance. On the one hand, both the profit and the value that big fish generate grow with the number of little fish that open the market. On the other hand, the big fish realize that profit by eating the little fish which, in turn, discourages the little fish from playing their market-opening role. Indeed, we have shown that this market evolution will, in the absence of patent rights, result in less than an optimal entry by the little fish innovators. This creates an obvious role for a well-defined patent policy that can offer some degree of protection to the inventive pioneers.

In the absence of either enforceable patent rights or fast-second entry, the number of entrepreneurial little fish will be too great, reflecting the standard result that horizontal product differentiation leads to excessive product variety. In this case, a patent regime offers a means of achieving the first-best social optimum because by offering patent rights that are sufficiently broad that they limit initial entry. Specifically, we find here that patents should be broader in markets with high set-up costs, weak price competition and slow market growth.

However, once we allow for the fast-second big fish to enter the market, designing the optimal patent policy becomes more challenging. In the absence of patent rights, the market is characterized by suboptimally low innovative entry as fear of the big fish’s eventual market dominance scares off potential entrants. In these circumstances patents can help restore a better balance. A key implication of our analysis is that for a patent regime to be able to achieve the first-best outcome it must, somewhat paradoxically, grant fairly broad patents. Although such breadth reduces the maximum number of entrepreneurs possible, the protection and higher profit that accompany such broad rights raises the number of innovators that actually do enter.
Broad patents encourage entry for two reasons. First, they expand the market area and increase the profits of the little fish entrepreneurs in the early stages of the market before a big fish fast second enters. Second, patents protect the surviving innovative firms from price competition with the fast second after it is in the market. If consumer tastes are “strong enough” these effects make it possible to design a first-best patent regime that leads to optimal innovative entry. However, if consumers are only weakly attached to their most preferred product variety, the patent system must settle for a second-best outcome that maximizes the social surplus subject to the constraint that innovative entrants at least break. This patent design will still raise the level of entry over what it otherwise would have been but it will limit entry below the first-best socially optimal level. With weak consumer attachment to a local variety, the fast second big fish can devour many little fish entrepreneurs when it enters and this deters entry. The second-best patent must generate enough profit to balance this disincentive.
References


