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Cannibalization, Innovation, and Spin-outs

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Abstract

How does a firm decide which products to introduce when faced with the cannibalization of profits from its current offerings? In a simple spatial model of imperfectly substitutable products, we show that when the cost of product development is fixed, the firm must take into account the impact on both the lowered profits of its current offerings and the profits from the new product. As a result, there is a gap between the firm's offerings. The substitutability of the products, the cost of product development and the magnitude of demand all impact this distance. When the cost of product introduction increases with the distance between the old and new products, the firm will offer those products that are sufficiently far away from its current offerings, but will not offer a new product if it is \too" far away from its current offerings. Hence, the range of its possible offerings is smaller. The fixed cost of product development, the substitutability of the products and the magnitude of demand help to determine the gap between the products and the increased cost of product development due to fit limits the range of product offerings. We investigate the impact of external competition and show that firms will introduce new products further from their current offerings when there is a threat of competition. When the firm cannot prevent a spin-out, it is more likely to introduce a new product, and to discard a new product even when it is not efficient to do so. Jelcodes:L00,-

Cannibalization, Innovation and Spin-outs

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April 20, 2012

Abstract

How does a firm decide which products to introduce when faced with the cannibalization of profits from its current offerings? In a simple spatial model of imperfectly substitutable products, we show that the cost of product development determines the range of new products a firm will offer. When the development cost is fixed, there is a gap between the firm's offerings, and when the cost increases with the distance between the old and new products, in addition to a gap between products, the firm will not develop new products that are "too" far from its current offerings. The substitutability of the products, the fixed cost of product development and the magnitude of demand all impact the gap between products and the increased cost of product development due to fit limits the range of product offerings. We investigate the impact of competition that arises from within the firm, spin-outs, where a former employee can leave with an idea developed within the firm. Without the use of informational asymmetries, we show that the outcome can be inefficient. This inefficiency arises due to the firm with the higher development costs introducing the product or because a valuable product is not developed.

1 Introduction

How firms respond to competitive threats from other firms has been a subject of considerable interest both theoretically (Gilbert and Newbery, 1982; Reinganum, 1983; Reinganum, 1984; Cassiman and Ueda, 2006) and empirically (Chandy and Tellis, 2000; Christensen, 2003). However, less attention has been given theoretically to the issue of cannabilization of existing products as seen as the loss of profits due to the substitution of new products for older products, though empirical wok points to its importance for the firm's overall strategy. In this paper, we address three main questions. First, what determines when a firm will produce new products which may provide additional profits, but may lead to the lower profits from existing products? Second, how does the fit between the old and the new products in terms of cost of development impact the firm's decision to produce a new product? Finally, when the firm faces a new competitor which is headed by a former employee, how does this impact overall efficiency?

In a simple spatial setting where consumers' preferences are uniformly distributed, we show that a firm is more likely to produce multiple products which may compete for the same consumers the lower the cost of product development, the higher the substitutability between the firm's products, and the higher overall demand for an individual product. This means that there will gaps in the product space since the firm can only recoup the cost of development without infringing on its current products when the products are sufficiently far apart in the product space. This provides a rationale for the existence of gaps in the product space that are identified in de Figueiredo and Silverman (2007). In particular, the lumpiness in the product space is due to the substitutability between products and the fixed cost of development. The firm will only develop those products that where the marginal return is higher than the cost of product development. A firm will introduce a new product as long as it is sufficiently far from its current offerings; those that are too close will be shelved.

We also consider the impact of fit on the firm's product introduction strategy. Fit in this model is measured by the increased cost of introducing a new product due to its closeness to the firm's current offerings. The firm may find products that are close to its current offerings to be cheaper to introduce due to brand reputation, advertising effects, or availability of equipment. In this case, we find that the firm will produce products that are sufficiently far from its current offerings, so that the new products do not cannibalize "too much" on its current profits, but not too far away, since this will increase the cost of introducing a new product and not be profitable. Unlike the previous case, the distance between firm's new offerings and its current offerings will limited, and the firm will be more focused in terms of total offerings. The range of the offerings will depend on the fixed cost of product development, the marginal cost of fit for product development, the relatively substitutability between products, and the overall demand for the product.

Next we consider the impact of competition arising from within the firm by way of spin-outs, firms created by former employees with knowledge of the innovations created by the firm. The range of products that the incumbent will introduce is larger, since this allows the incumbent to produce a defensive fence against potential competitors. Instead of simply comparing the cost of development with the marginal profits, the incumbent compares the cost against the monopoly profits of its current product. Because the entrant will lower the profits from that product, the incumbent will develop some products that it would not have developed when there was no possibility of entry. In addition, there are cases where the incumbent may buy the innovation from the researcher and then discard the innovation to prevent the cannibalization of its current products. Hence, this highlights the fact that inefficiencies may arise for two distinct reasons. The first is due to the fact that the firm with higher costs of product development introducing the new product, and the second results from the fact that fewer products are introduced. The first effect is well-known in the literature (Arrow, 1962), while the second effect has not been highlighted.

Finally, we show that the legislative environment matters; if covenants not to compete (CNC) are enforced, the incumbent can prevent any new competition from within. This is important since the incumbent's inability to do so leads it to engage in behavior that lowers social welfare. When CNC are not enforced, the incumbent must buy the innovation from its employee in order to prevent this competition from within.

Our work provides the microfoundations for understanding the product introduction choices made by firms in dealing both with competition between its own products and with competition that may arise from within the firm in the form of a spin-out. Given that the innovation that gives rise to a new product can be thought of as a patent, our work has important implications for anti-trust authorities. There are a number of papers that focus on the issue of sleeping patents and the impact on productivity as well as their anticompetitive effects (Palomeras 2003, However, our work suggests that simply observing a patent in use is not enough to determine whether or not the outcome is efficient. It is possible that the "wrong" firm has developed the product, since it may have higher costs of introducing the new product and has done so only to defend its own products. In addition, our model encompasses that of Gilbert and Newbery (1983) since patenting can be thought of as a spatial game in the presence of substitutability.

2 Monopolist

2.1 Monopolistic firm developing a substitutable product

A monopolistic firm M produces a single product y_i. The subscript i denotes the location of product x in a one-dimensional product space represented by a circle of circumference C in the manner of **?**. Consumers are uniformly distributed across product space with mass 1 at each point, and the willingness to pay for product i by a consumer at location z is

$$V(i, z) = \max\{\alpha - \beta|i - z|, 0\}. \tag{2.1}$$

That is, the consumer's valuation of the product is decreasing in the distance between the consumer and the product. The higher is β, the greater the value loss to a consumer who uses a product at some given distance from her location. Each consumer has unit demand and will use at most one product. The parameter β can therefore be viewed as an inverse measure of substitutability across product space: the lower is β, the lower the premium a consumer at location l is willing to pay for product l over some 'nearby' product.

The monopolist can price discriminate and so extract $V(i, z)$ from each consumer. The firm's total payoff π_M is the area of the triangle in Figure 1: $\pi_M = \frac{\alpha^2}{\beta}$.

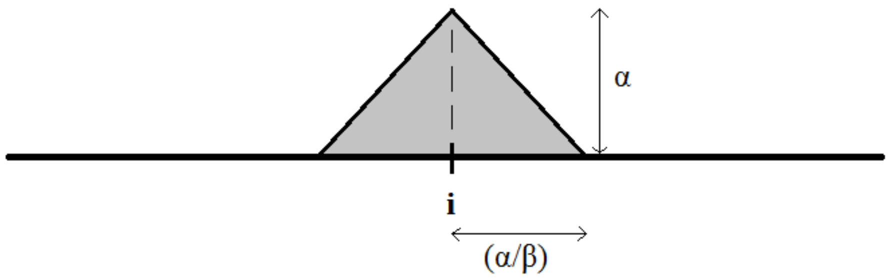


Figure 1: Willingness to pay for i by location

Say now that the firm receives an innovation x_j. The firm can develop the innovation into a product y_j at a fixed cost of $F \in (0, \frac{\alpha^2}{\beta})$ and add it to its portfolio of products, or do nothing and continue to sell only y_i.

If the firm develops the innovation, its payoff will increase: since $j \neq i$, some consumers who had zero willingness to pay for product i will be willing to pay some positive amount for j. But if j is 'close' to i, then the products' substitutability means that the marginal revenue of adding y_j is less than π_M. This is illustrated in Figure 2, in which the darker shaded area A is the marginal revenue of introducing y_j.

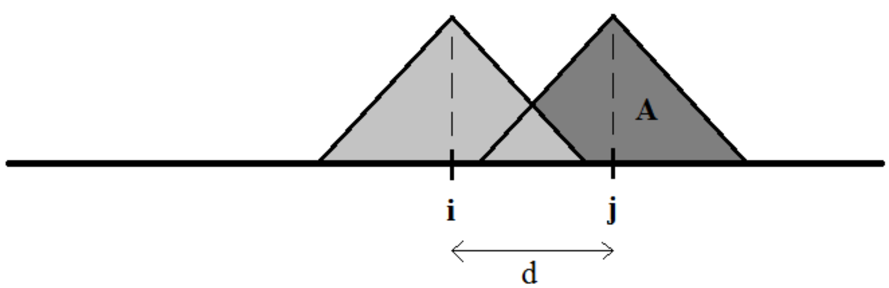


Figure 2: Marginal payoff to developing product x_j

Denote the distance $|i - j|$ by d_{ij}. Then the size of the area A - the marginal revenue of introducing y_j - is

$$\pi_j(d_{ij}) = \begin{cases} \alpha d_{ij} - \frac{1}{4}\beta d_{ij}^2 & \text{if} \quad d_{ij} < \frac{2\alpha}{\beta} \\ \frac{\alpha^2}{\beta} & \text{if} \quad d_{ij} \geq \frac{2\alpha}{\beta} \end{cases} \tag{2.2}$$

During that part of the domain of this function where $d_{ij} \in [0, \frac{2\alpha}{\beta})$, $\pi_j(d_{ij})$ is increasing and convex, ranging from 0 when $d_{ij} = 0$ to $\frac{\alpha^2}{\beta}$ when $d_{ij} = \frac{2\alpha}{\beta}$. Figure 3 illustrates the function; d_F^0 is the smallest distance such that the firm prefers to develop innovation x_j rather than discard the innovation, given the fixed cost F of development.

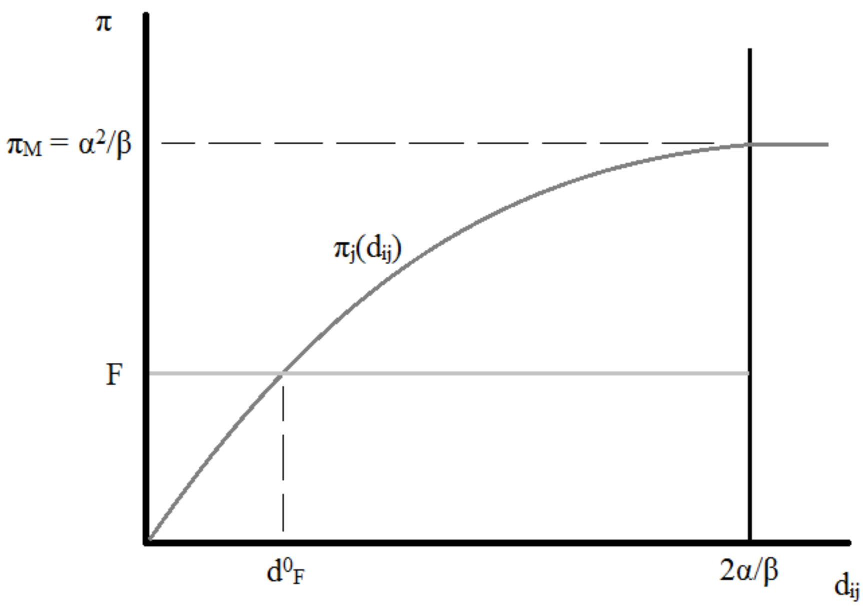


Figure 3: Profitable to develop x_j iff $d_{ij} > d_F^0$

Using this minimum development distance d_F^0, we can establish the following result, which imagines a repeated process of innovation arrival and development:

Proposition 1. *The maximal product variety produced by a monopolist when the cost of developing a product is fixed is*

i. *decreasing in the cost of product development F,*

ii. *increasing in product substitutability (the inverse of β), and*

iii. *increasing in demand magnitude* α*.*

The larger the minimum development distance, the fewer products the monopolist can profitably develop across the product space C. The distance d_F^0 thus defines the magnitude of 'holes' in product variety space, since the monopolist will never develop a new product if an existing one is within such a distance.

2.2 Adding product fit

Next we consider that the cost of developing an innovation at location j may itself depend on the distance between j and the existing product produced by the monopolist. For example, the expertise that the firm already uses to produce product y_i may be more readily adapted to produce y_j if j is 'close' to i. In a more abstract sense the cost of fit could capture the riskiness of developing products that are very different from the firm's existing line.

In the previous section the cost of developing x_j was fixed at F. To capture this new idea of the 'fit' of an innovation with the firm's existing product, let the cost of developing an innovation x_j be

$$c_j = F + \phi d_{ij}, \tag{2.3}$$

where again $F \in (0, \frac{\alpha^2}{\beta})$ and $\phi > 0$. Again the problem for the firm is whether to develop the innovation.

If there was no substitutability between the old and new products, this cost structure would imply some maximum distance beyond which the innovation would not be developed. However, fit in conjunction with substitutability implies at best a 'window' in which the monopolist can profitably develop innovations. If the innovation is too close to i, substitutability means that marginal revenue is too low, but if the innovation is too far from i, poor fit means that development cost is too high.

The following result formalizes this notion:

Proposition 2. *If* $\beta F > (\alpha - \phi)^2$*, there exists no innovation* x_j *that the firm will develop. If* $\beta F \leq (\alpha - \phi)^2$*, then there exist* $\underline{d}$*,* $\overline{d}$*, where* $\overline{d} \geq \underline{d} > 0$*, such that the firm will develop* x_j

when

$$d_{ij} \in [\underline{d}, \overline{d}], \tag{2.4}$$

and where $\underline{d}$ is smaller and $\overline{d}$ is larger

i. *the smaller is the fixed cost of development F,*

ii. *the smaller is the cost of fit ϕ,*

iii. *the greater is substitutability (smaller β), and*

iv. *the greater is demand magnitude α.*

Figure 4 illustrates the window of profitable development.

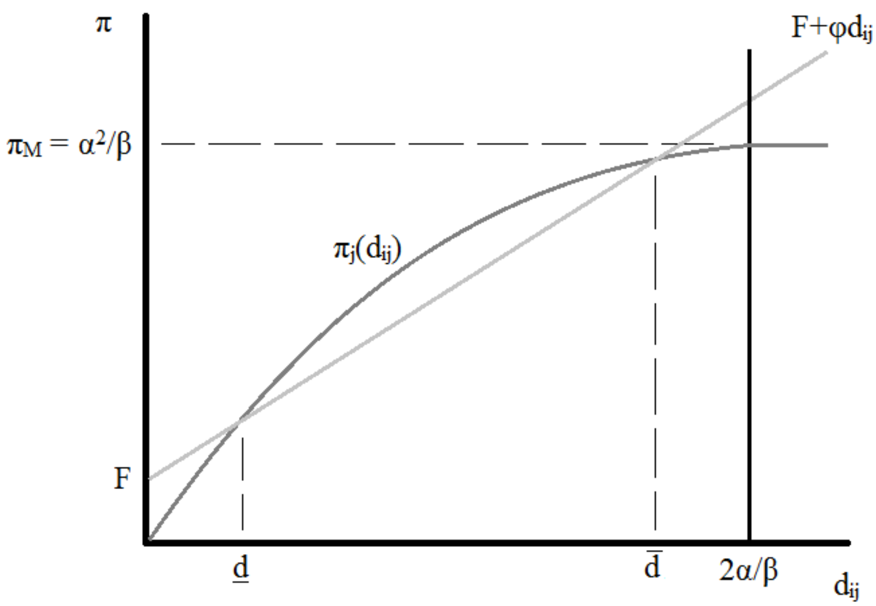


Figure 4: Profitable to develop x_j iff $d_{ij} \in [\underline{d}, \overline{d}]$

Proposition 2 establishes that this window is bigger when the fixed cost of development and the cost of fit are smaller, and when the parameters that capture the 'size' of demand are larger. An analogous result will hold from an initial state when the monopolist's portfolio has more than one product; it will be profitable to develop within some window from the *closest* existing product.

The notion of fit implies a dynamic process by which successive innovations are either developed or not; an innovation that is far from the monopolist's portfolio today (and thus not developed) may later be close as the portfolio expands. Proposition 2 therefore implies a process by which the monopolist's product portfolio expands incrementally into new areas, rather than sudden jumps into new products that are far from its existing offerings. Nevertheless, in this case with fit the maximal product variety across the space C is subject to the same forces as in Proposition 1. Thus maximal variety is again increasing in α, decreasing in β and decreasing in the cost parameters F and ϕ.

3 Potential competition

3.1 Entry and competition

So far we have considered the problem for a monopolist deciding whether to develop an innovation. This section will consider the problem for a potential competitor who must decide whether to enter the industry by developing a given innovation, and how this in turn affects the problem for the incumbent monopolist of the previous sections.

If a competitor develops a product sufficiently close to the incumbent's existing portfolio, there will be some consumers in an overlapping region who have positive willingness to pay for both products. We assume Bertrand competition over the common portion of this willingness to pay.

Figure 5 illustrates this competitive effect. If the entrant draws and develops an innovation at location j, then neither firm is able to extract from common consumers that portion of willingness to pay that is common to both firms. Thus the area A is the revenue earned by the entrant at j, but the revenue earned by the incumbent at i is also reduced in a manner that it was not in the case when the incumbent was itself the developer of j (as in Figure 2).

The revenue to the entrant from developing at j is identical to that earned by the monopolist. However, we allow for the possibility that the entrant faces a different cost of

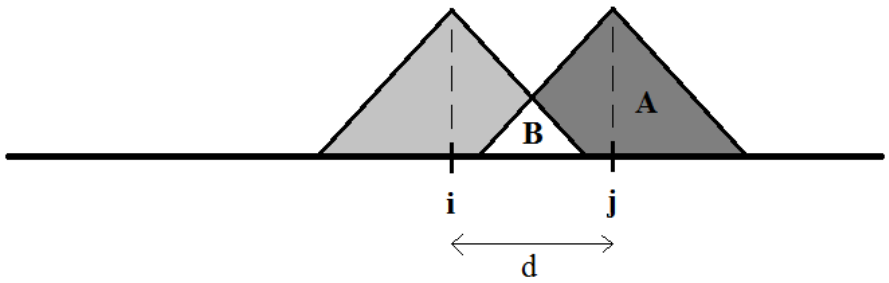


Figure 5: When an entrant develops at j, competition reduces surplus extracted from overlapping consumers

development; denote by E the fixed cost to the entrant of developing its first product. Again $E \in (0, \frac{\alpha^2}{\beta})$, but $E > F$, the fixed cost of development for the monopolist (equivalently, the monopolist's cost of development absent a cost of fit).

By analogy with the case of the monopolist with fixed development cost F, there thus exists d_E^0 such that when the incumbent is producing a product at i, the entrant will develop an innovation at j if and only if $d_{ij} > d_E^0$.

3.2 Potential entry and defensive development

Fix the incumbent's portfolio as a single product y_i. Consider the following game:

1. Innovation x_j is drawn by both the incumbent and entrant.
2. The incumbent chooses whether to develop product y_j.
3. The entrant observes the incumbent's decision and chooses whether to develop product y_j.

This is the simplest model of potential entry: an innovation at location j is 'in the air', and the incumbent firm may choose as before whether or not to develop it. However, now if the incumbent does not develop at location j, a potential entrant can choose whether to develop at the same location. The question of interest is how this potential entry changes the problem for the incumbent relative to that in Section 2.2.

Proposition 3. *The incumbent develops at j if and only if*

i. $d_{ij} \in [\underline{d}, \overline{d}]$, *or*

ii. $d_{ij} > d_E^0$ *and* $\pi_M > c_j$.

The first case in this result is that the incumbent will develop if it is unilaterally profitable to do so. But when there is potential entry there may be a larger region in which the incumbent will develop: the second case defines those innovations that would not be unilaterally profitable for the incumbent but that it will choose to develop defensively.

To see the reason for the second case, consider the situation in which the incumbent forgoes developing at a location that 'overlaps' its existing base and the entrant goes on to develop. The incumbent has foregone the marginal revenue of the new product (the area A in Figure 5) but has saved the cost of development c_j. But when the entrant develops, the incumbent also loses the area B in Figure 5 through competition between the products y_i and y_j. Thus the total loss to not developing is $A + B = \pi_M$; if the saving c_j does not exceed this amount, the incumbent will develop, even if $A < \pi_M$.

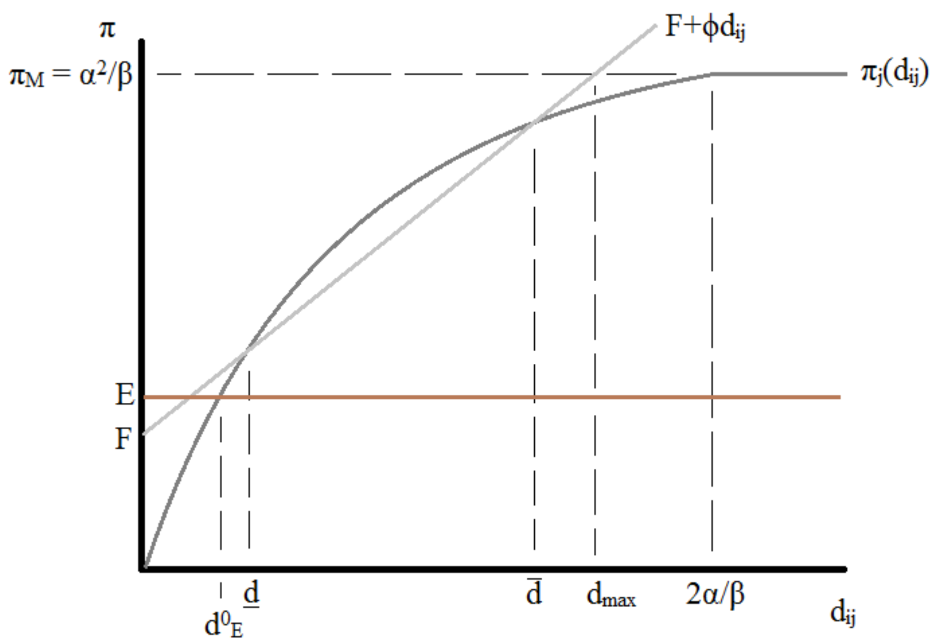


Figure 6: Incumbent will develop at j if $d_{ij} \in [d_E^0, d_{max}]$

Figure 6 illustrates how the window in which the incumbent is willing to develop can expand in the face of a potential entrant. Now the incumbent will prefer to develop any innovation x_j so that $d_{ij} \in [d_E^0, d_{max}]$. Thus the incumbent develops if the innovation arrives in this window, and the entrant develop if the innovation arrives so that $d_{ij} > d_{max}$. Note that it is in general possible that the window expands in both directions, either direction or neither direction, depending on E and the crossing point between c_j and π_M.

The conclusion of this simple incorporation of potential entry will generalize readily to a slightly different case. If the incumbent first draws an innovation at j and then the entrant draws from a distribution of possible innovations, it will again be the case that the incumbent may engage in defensive development, depending on the shape of the distribution from which the entrant will draw.

4 Researcher incentives

Next we add to the model the notion that an idea arrives to a specific researcher. If an idea arrives to a researcher who is employed by the incumbent firm, the firm may or may not elect to develop the innovation, but it also could be that the researcher ultimately develops the innovation outside the firm. This is related to the simple game in the previous section: depending on the institutional regime, if the firm passes on developing an idea x_j, the researcher could become an 'entrant' by taking the idea and developing it privately. We assume throughout that the arrival and location of an idea are known to both the researcher and the firm, so that there is no asymmetric information.

Say that initially the incumbent monopolist M employs a researcher R at a reservation wage of 0. When R receives an innovation at location j, then there are three broad possibilities for where this idea x_j ends up. First, the idea could be developed into product y_j by M. Second, it could be developed into y_j by R, outside the firm. Third, it could be discarded and developed by neither party. Assume for the moment that the researcher retains control of the idea when it arrives, so that she is free to leave and develop the idea privately should she so choose[1].

[1]This is without loss of generality to the ultimate outcome for the development of the idea, although it

	Developed by R	Developed by M	Discarded
M's payoff	$-(\pi_M - \pi_j)$	$\pi_j - c_j$	0
R's payoff	$\pi_j - E$	0	0

Table 1: Payoffs to the researcher and firm, gross of transfers

Absent any transfers between the researcher and the firm, Table 1 shows the payoffs to each party under each of these possibilities. The loss to the incumbent should the researcher ultimately develop at j outside the firm is precisely the area B in Figure 5.

Since the researcher has the 'right of first refusal' to the idea, should the firm want to develop or discard the idea, it must compensate the researcher to reflect that she could have developed the idea privately. This implies a game with the following order of play:

1. Innovation x_j is drawn by R.

2. M offers a payment $p \geq 0$ to retain R and x_j.

3. R accepts or rejects p.

4. **a)** If R accepts, p is transferred from M to R and M chooses to develop or discard x_j.

   b) If R rejects, R chooses to develop or discard x_j.

This means that if the idea would be profitable for the researcher privately, the firm must pay at least $p = \pi_j - E$ (if this amount is positive) to satisfy the researcher's incentive compatibility constraint if it is to retain internally the right to develop idea x_j. In this case Table 2 shows payoffs net of the transfers that must take place in each case.

	Developed by R	Developed by M	Discarded
M's payoff	$-(\pi_M - \pi_j)$	$E - c_j$	$-(\pi_j - E)$
R's payoff	$\pi_j - E$	$\pi_j - E$	$\pi_j - E$

Table 2: Payoffs to the researcher and firm, net of transfers

The following result then establishes the outcome for x_j in subgame perfect equilibrium.

would not be to the contracting problem between the researcher and the firm.

Proposition 4. *1. x_j is developed by R if $E < \pi_j$, $E < c_j - (\pi_M - \pi_j)$ and $E < 2\pi_j - \pi_M$.*

2. x_j is developed by M if either

a. *$c_j < \pi_j$ and $E > \pi_j$, or*

b. *$c_j < \pi_j$, $E < \pi_j$ and $E > c_j - (\pi_M - \pi_j)$.*

3. x_j is discarded if either

a. *$c_j > \pi_j$ and $E > \pi_j$, or*

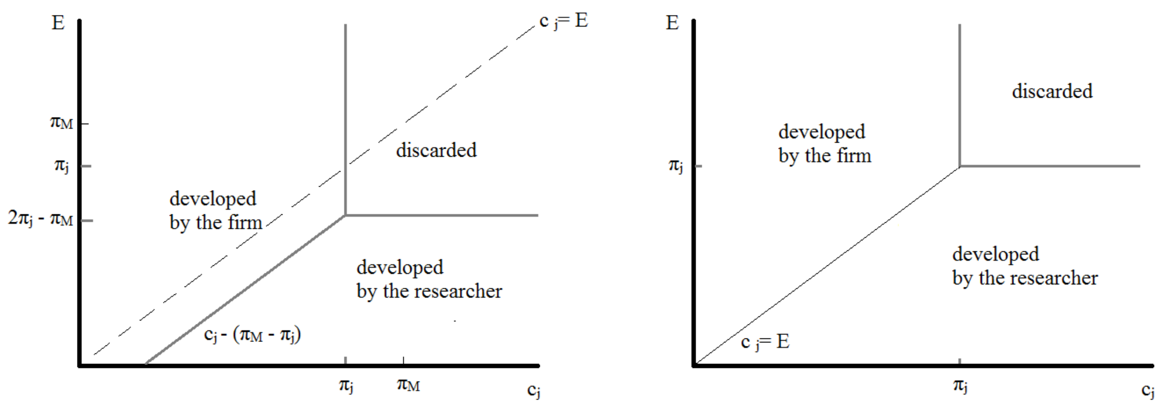
b. *$c_j > \pi_j$, $E < \pi_j$ and $E > 2\pi_j - \pi_M$.*

Cases 2b. and 3b. are related to the defensive development observed in the model in Section 3.2. In both of those cases, the researcher could be profitable by developing the idea outside the firm, but the firm prefers and can afford to pay not to allow it. However, now there are two possibilities: the firm need not *develop* to defend, but as in 3b. can pay to retain and shelve the idea. The parameters of the model therefore enter into Proposition 4 in two distinct ways. For example, there are two broad effects of E. Larger E certainly makes it less likely that the researcher can profitably enter, but it also reduces the payment p that the firm must pay to retain the researcher and the idea.

The socially efficient outcome in this game would be for the idea developed if at least one of the firm or researcher can do so profitably, and if both could develop profitably, for the player with the lowest cost to develop. This efficient outcome will not in general prevail so long as π_j is less than π_M – that is, so long as the firm's original product and the idea at j are 'overlapping'. There are always cases in which an idea which 'should' be developed by the researcher is developed instead by the firm, and cases in which an idea 'should' be developed by the researcher and instead is discarded.

An implication is that to tell whether 'good' use is being made of an idea, it is not sufficient just to observe whether or not it is being developed. Even in the simple environment of the model, without contracting problems or other frictions, it can be that the firm that develops the idea has reached 'too far' into product space to develop it, in order to avoid the competitive loss from allowing the idea to be better developed elsewhere.

Further, the severity of the inefficiency - the range of parameter values for which inefficient outcomes prevail - depends on the location of the idea. Figure 7 illustrates side-by-side the equilibrium and efficient outcomes for a 'high value' idea: one which is relatively 'far' from the firm's original location.



(a) Equilibrium outcome

(b) Socially efficient outcome

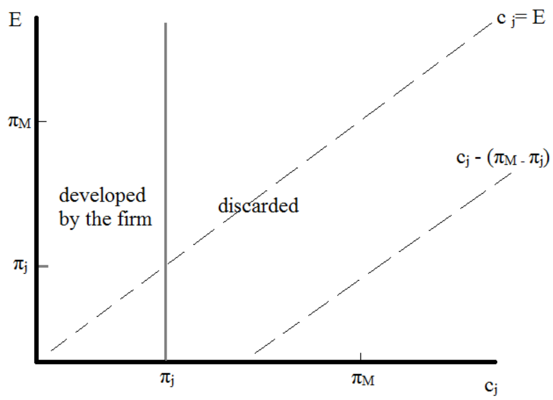
Figure 7: Equilibrium and efficient outcomes for a 'high value' idea

We can see that there are regions in which the inefficient outcome is not realized. For example, the region in which an idea is discarded is larger than the efficient region. This is because in the extra area E is sufficiently low that the researcher could be profitable, but sufficiently high that the payment the firm has to make to retain and discard the idea (rather than suffer a competitive loss) is low.

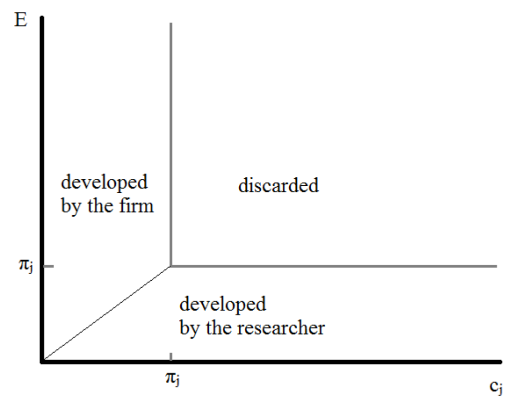
But the closer the idea is to the firm's original location, the more severe the discrepancy. Figure 8 repeats the previous exercise for an idea that is close to the original location and so of 'low value'.

The closer the idea, the larger the region of inefficient outcomes: the potential payoff to the researcher by developing privately is small, and so the firm can cheaply buy out the idea to avoid the competitive loss or realize the gain itself. The parameter region in which we would observe a researcher leave the firm to develop her idea is also being squeezed. This may imply an inefficiently small product variety, as 'close' ideas may be underdeveloped, especially if the fit problem is high.

Figure 9 repeats the exercise of the previous figures, but for arbitrarily fixed values of the



(a) Equilibrium outcome



(b) Socially efficient outcome

Figure 8: Equilibrium and efficient outcomes for a 'low value' idea

cost and demand parameters and variable distance. The numbered regions correspond to the numbered outcomes in Proposition 4, so that the regions 2b and 3b correspond to the cases in which it is socially efficient that the researcher develop her idea, but the firm develops it (2b) or it is discarded (3b).

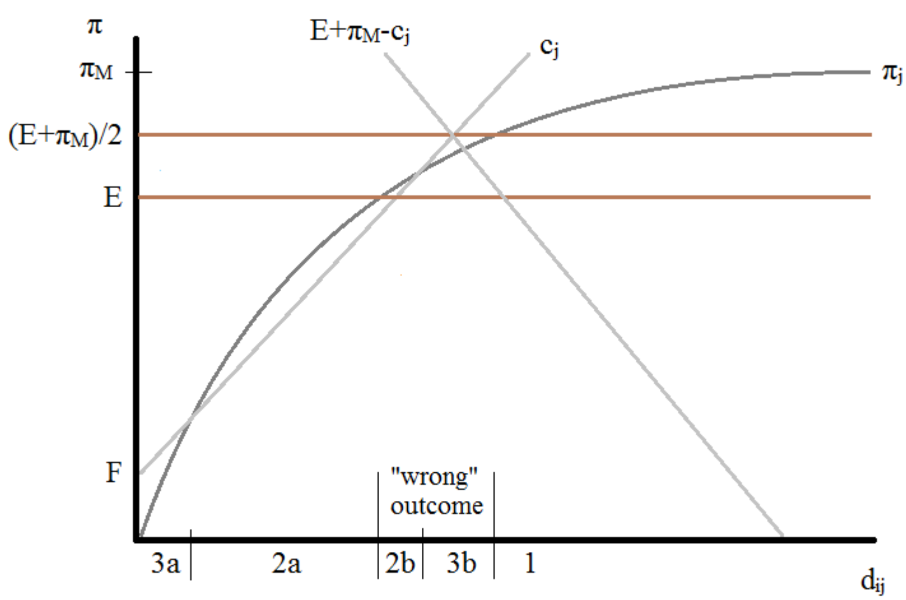


Figure 9: Inefficient outcomes occur at intermediate distance

These inefficient outcomes appear for ideas that are neither too close nor too far from the original product i. For very close ideas (regions 3a and 2a), the fit problem for the incumbent is low and so its development cost is low relative to the cost for the researcher to set up: either the idea is too close to be usable or it is (efficiently) developed by the firm. For very far ideas (region 1), the fit problem is more severe for the incumbent, it is very expensive for the incumbent to buy the idea from the researcher, since the profitability of the idea is high, and the loss to the incumbent is relatively small. It is therefore efficient that the researcher develop the idea privately. Between these two regions, the fit problem is severe enough so that the startup would be more efficient, but the loss to the incumbent from allowing the startup is still high enough and the cost to buy the idea still low enough that the incumbent prefers not to allow the researcher to develop privately.

5 Conclusion

Our paper addresses the issue of how firms decide on which products to introduce when new products may cannibalize the profitability of their current products. We show that when the cost of developing new products is constant, the firm will develop products that are not close substitutes with its current offering. This leads to a gap between its product offerings. When the cost of development increases in the spatial distance from its current product and the new product, the firm will develop a smaller range of products. There will still be a gap between its products, but it will be unwilling to develop a new product that is too far afield from its current product. This increase in costs may be due to a lack of marketing experience, or production expertise in the new area. The gap between products is increasing in the fixed component of the development costs, and decreasing in the substitutability between products and the overall demand for the products. The range of products that a firm would be willing to offer when there are fit considerations is increasing in substitutability between products, and the overall demand for the products and is decreasing in the fixed and marginal costs of development.

Further we show that incumbents which face entrants that arise from within the organization may choose to optimally defend their current offerings by buying the ideas from their own researchers. Here the set of products that an incumbent will produce may be larger than in the case where the incumbent does not face any competition; the incumbent may develop a product to protect its current product from cannibalization from an entrant. In addition, the incumbent may buy and discard a new product in order to protect its current product. Thus, social welfare is lowered either due to the firm with the higher cost of development producing the new product, or because the product is not produced. Further, we show that the relationship between market value and inefficiency is negative. As the overall value of the market increases, the inefficiency due to the incumbent's defensive behavior falls.

There are a number of avenues for future research. First, our work focuses on the impact of an innovative process that is not focused. One avenue would be to consider what happens when the firm can choose which products to produce and the order in which it may choose to produce its products. Does it produce new products further and further away from its original product or does it backfill, producing first further away and then producing products closer to its original product? Second, our work focuses on the case where products vary in their degree of substitutability. Another avenue is to study the case where products vary in their degree of complementary and the firm is limited in terms of its resources. Under what conditions would it be will to have another firm produce a complementary product to its own? This could help address the question of industry architecture and how firms may choose to affect it. Finally, our work focuses on the case where the market value of each product is the same. One may ask how differences in product values affect the analysis.

Our results have important implications for policy makers. There has been a recent focus on the use of sleeping patents as an anticompetitive tool for firms (Palomeras 2003), but our work suggests that patents which are used by firms may also have anticompetitive implications. In addition, our work shows that even without information asymmetries, difference legislative regimes, such as the enforcement or lack of enforcement of CNC, can lead to very different outcomes. Typically work in the area has relied on information asymmetries between agents for differences in outcomes (Franco and Mitchell 2008). However, this provides a very intuitive rationale for these differences in economic outcomes; because a firm must pay its researchers to prevent cannibalization of its product, the firm's optimal actions change and it tends to become more defensive and invests in less profitable innovations than it would have otherwise.

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A Proofs

Proposition 1

Proof. The product space is a circle with circumference C, and so the maximal product variety of the monopolist is $\lfloor \frac{C}{d_F^0} \rfloor$, which is decreasing in d_F^0.

$\pi_j(d_F^0) = F$ by definition, so that d_F^0 is that d which solves $\alpha d - \frac{1}{4}\beta d^2 - F = 0$. Since π_j is continuous and strictly concave while $d < \frac{2\alpha}{\beta}$ and takes values 0 at $d = 0$ and π_M at $d = \frac{2\alpha}{\beta}$ and since $F \in (0, \pi_M)$, it must be that d_F^0 is the smaller of the two roots of $\alpha d - \frac{1}{4}\beta d^2 - F = 0$ and lies between $d = 0$ and $d = \frac{2\alpha}{\beta}$.

Thus $d_F^0 = \frac{2\alpha - \sqrt{4\alpha^2 - \beta F}}{\frac{1}{2}\beta}$, and so $d_F^{0\prime}(F) > 0$, $d_F^{0\prime}(\alpha) < 0$, $d_F^{0\prime}(\beta) > 0$. Since maximal product variety is decreasing in d_F^0, this completes the proof. □

Proposition 2

Proof. $\pi_j = 0$ at $d = 0$ and is strictly increasing and concave up to $d = \frac{2\alpha}{\beta}$ and is constant at $\frac{\alpha^2}{\beta}$ when $d \geq \frac{2\alpha}{\beta}$. At $d = 0$, $c_j = F > \pi_j$, and c_j is strictly increasing with $c_j'(d) = \phi \forall d$.

Thus $\pi_j < c_j \forall d$ if and only if $\nexists d$ such that $\pi_j = c_j$. $\pi_j = c_j$ when $d = \frac{(\alpha-\phi) \pm \sqrt{(\alpha-\phi)^2 - \beta F}}{\frac{1}{2}\beta}$, and so if $\beta F > (\alpha - \phi)^2$ then $\nexists d$ such that $\pi_j = c_j$. Then $\pi_j < c_j \forall d$ and so no innovation will be developed at any distance.

If $\beta F = (\alpha - \phi)^2$ then $\pi_j = c_j$ when $d = \frac{\alpha - \phi}{\frac{1}{2}\beta}$ and so the firm will develop if $d = \frac{\alpha-\phi}{\frac{1}{2}\beta}$.

If $\beta F < (\alpha - \phi)^2$ then $\pi_j \geq c_j$ when $d \in [\underline{d}, \overline{d}]$, where $\underline{d} \equiv \frac{(\alpha-\phi) - \sqrt{(\alpha-\phi)^2 - \beta F}}{\frac{1}{2}\beta}$ and $\overline{d} \equiv \frac{(\alpha-\phi) + \sqrt{(\alpha-\phi)^2 - \beta F}}{\frac{1}{2}\beta}$ if $\frac{(\alpha-\phi) + \sqrt{(\alpha-\phi)^2 - \beta F}}{\frac{1}{2}\beta} < \frac{2\alpha}{\beta}$ and $\overline{d} \equiv \frac{1}{\phi}(\frac{\alpha^2}{\beta} - F)$ otherwise. Since $\pi_j \geq c_j$ when $d \in [\underline{d}, \overline{d}]$ the firm will develop if $d_{ij} \in [\underline{d}, \overline{d}]$.

$\underline{d}'(F) > 0$, $\underline{d}'(\phi) > 0$, $\underline{d}'(\beta) > 0$ and $\underline{d}'(\alpha) < 0$; $\overline{d}'(F) < 0$, $\overline{d}'(\phi) < 0$, $\overline{d}'(\beta) < 0$ and $\overline{d}'(\alpha) > 0$. This completes the proof. □

Proposition 3

At stage 3, if the entrant chooses to develop y_j it will earn $-E$ if the incumbent developed in stage 2 and $\pi_j - E$ if the incumbent did not develop in stage 2. The entrant will thus develop if and only if the incumbent did not develop and $\pi_j > E$.

By backward induction, at round 2 the incumbent therefore earns $\pi_j - c_j$ by developing y_j. If it chooses not to develop x_j, it earns 0 if $\pi_j < E$ and $(\pi_j - \pi_M)$ if $\pi_j - E > 0$, since in the latter case the entrant will enter and compete away some of the incumbent's existing surplus.

If $\pi_j > c_j$, the incumbent will thus either earn $\pi - c_j$ by developing y_j and earn at most zero by not developing. Therefore if $\pi - c_j > 0$, the incumbent will choose to develop at stage 2.

If $\pi_j > E$, the incumbent will either earn $\pi_j - c_j$ by developing y_j and lose $(\pi_j - \pi_M)$ by not developing, and so will choose to develop if and only if $\pi_j - c_j > \pi_j - \pi_M$; that is, if $\pi_M > c_j$. Since $d_{ij} > d_E^0$ only when $\pi_j > E$, the incumbent will thus choose to develop at stage 2 when $d_{ij} > d_E^0$ and $\pi_M > c_j$.

If neither $\pi_j > c_j$, $d_{ij} > d_E^0$ and $\pi_M > c_j$, then the incumbent earns zero by not developing and less than zero by developing. Thus the incumbent develops y_j only if $\pi_j > c_j$, or $d_{ij} > d_E^0$ and $\pi_M > c_j$.

Proposition 4

In stage 4b), R will develop if and only if $\pi_j > E$. In stage 4a), M will develop if and only if $\pi_j > c_j$.

In stage 3, R earns $\max\{\pi_j - E, 0\}$ by rejecting p and earns p by accepting. R thus rejects in stage 3 if and only if $p > \max\{\pi_j - E, 0\}$.

First consider the case in which $\max\{\pi_j - E, 0\} = 0$. Then in stage 2 M earns $-p$ by offering $p > 0$, since then R will accept and choose not to develop. If M offers $p = 0$, R will accept in stage 3 and so M will have the idea and earn $\max\{\pi_j - c_j, 0\}$. Since $\max\{\pi_j - c_j), 0\} \geq 0$, M will offer $p = 0$, buy the idea, and develop the idea if and only if $\pi_j - c_j$. Thus if $c_j < \pi_j$ and $E > \pi_j$ the idea will be developed by M (case 2a.) and if $c_j > \pi_j$ and $E > \pi_j$ the idea will be discarded (case 3a.).

Next consider the case in which $\max\{\pi_j - E, 0\} = \pi_j - E$. If M offers $p < \pi_j - E$ then R will reject and choose to develop the idea. In this case M earns $-(\pi_M - \pi_j)$ due to the competitive loss. If M offers $p \geq \pi_j - E$ then R will accept. M will then earn $-p + \max\{\pi_j - c_j), 0\}$; since in this case $p = \pi_j - E$ strictly dominates any $p > \pi_j - E$ we can restrict attention to $p = \pi_j - E$. M will thus offer $p = \pi_j - E$ if and only if $-(\pi_j - E) + \max\{\pi_j - c_j, 0\}$.

Of these consider first the case in which $\max\{\pi_j - c_j, 0\} = 0$. Then M earns $-(\pi_j - E)$ by offering $p = \pi_j - E$ and earns $-(\pi_M - \pi_j)$ by offering a smaller p. Thus if $\pi_j > E$, $\pi_j < c_j$ and $-(\pi_j - E) > -(\pi_M - \pi_j)$, then M buys the idea and discards it (case 3b.)

Next consider $\max\{\pi_j - c_j, 0\} = \pi_j - c_j$. In this case M will develop the idea if it buys it an so earns $-(\pi_j - E) + (\pi_j - c_j) = E - c_j$ by offering $p = \pi_j - E$. Again M earns $-(\pi_M - \pi_j)$ by offering a smaller p since then R will not accept. Thus if $\pi_j > E$, $\pi_j > c_j$ and $E - c_j > -(\pi_M - \pi_j)$, then M buys the idea and develops it (case 2b.).

Finally, retaining that $\pi_j > E$, if neither $-(\pi_j - E) > -(\pi_M - \pi_j)$ nor $E - c_j > -(\pi_M - \pi_j)$, then M earns a higher payoff by offering a p lower than $\pi_j - E$ than its maximal payoff by offering $p = \pi_j - E$, and so M offers this lower p, R rejects and develops the idea (case 1).