# Start-Up Commercialisation Strategy and Innovative Dynamics

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# Start-Up Commercialisation Strategy and Innovative Dynamics*

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This paper endogenises a start-up's choice between competitive and cooperative commercialisation in a dynamic environment. It is demonstrated that, depending upon firms' dynamic capabilities, there may or may not be gains to trade between incumbents and start-ups in a cumulative innovation environment; that is, start-ups may not be adequately compensated for losses in future innovative potential. Because of this, there is no clear relationship between observed inter-industry innovation and commercialisation choice unless dynamic capabilities of firms are taken into account. In addition, the analysis demonstrates subtle and novel insights into the relationship between dynamic capabilities and rates of innovation. *Journal of Economic Literature* Classification Number: O34.

*Keywords*. innovation, incumbency, dynamic capabilities, licensing, commercialisation.

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One of the most fundamental issues in the relationship between market structure and innovation is whether technological trade or cooperation between firms that might otherwise compete is possible (and under what circumstances such trade might occur). For example, after early analyses of one-shot innovation races suggested that overinvestment was possible (e.g., Gilbert and Newbery, 1981; Reinganum, 1989), others demonstrated that the possibility of licensing (or cooperation in general) overturned these key conclusions and pointed towards alternative predictions regarding the nature of technological competition when licensing was feasible (Salant, 1982; Katz and Shapiro, 1987).

Complementing this, a recent set of papers has explored the rationale for differing commercialisation strategies: that is, whether start-ups choose to *compete* head-to-head with incumbents in product markets or alternatively *cooperate* with them through licensing, alliances or acquisition activity in markets for ideas.[1] Teece (1987) emphasised that cooperation was mutually beneficial for incumbents and start-ups as it avoided the duplication of critical complementary assets that would be required when start-ups chose to enter product markets. Gans and Stern (2000) built on this and explored the way in which licensing might avoid the dissipation of monopoly rents but also how intellectual property protection might facilitate such cooperative commercialisation by removing expropriation risk that might otherwise cause start-ups to avoid direct negotiations with incumbents (see also Anton and Yao, 1994; Arora, 1995). These drivers of cooperative commercialisation – that is, the importance of complementary assets and the strength of intellectual property protection – were borne out in empirical investigations by Gans, Hsu and Stern (2002), Arora and Ceccagnoli (2005) and Hsu (2005) who also considered the

[1] See Gans and Stern (2003) for a review.

importance of intermediaries in markets for ideas as facilitators of cooperation across industries.

This literature suggests two key conclusions regarding start-up commercialisation and innovation. First, that cooperative commercialisation and opportunities for it will increase start-up innovative incentives. Put simply, the returns that can be achieved through cooperative commercialisation factor into account a start-up's potential return from competition (as this is always an alternative for them). Thus, cooperative commercialisation choices will be correlated with higher innovative incentives for start-up firms. This suggests that the share of start-up or entrant innovation in an industry will be higher where cooperative commercialisation is more commonly observed.

Second, that there are overwhelming reasons why gains from trade in markets for ideas should be positive and that the main reason such trade is not observed is some failure in that market. Market failure could arise from weakness of property rights, information asymmetry impeding efficient bargaining or high search costs for cooperative partners (Gans and Stern, 2003). These cause cooperative agreements not be realised and competition to occur by default.

For the most part, these key conclusions reflect a static intuition and potentially neglect important dynamic considerations. For example, many teaching cases examining start-up commercialisation choices highlight important internal debates regarding the immediate gains from licensing or acquisition versus the concern that the start-up might be selling out to early and losing their 'birthright' to future innovative returns (Cape, 1999) or otherwise "mortgaging away" their company's future (Pisano, 1994, p.10). These debates suggest that when there are opportunities for future innovative development cooperation that pre-empts future competition denies start-ups important incumbency rents that cannot be compensated by current payments in ideas markets. That is, there is a suggestion that the gains from trade from cooperative commercialisation might not always be positive. Thus, cooperation might not be observed even where ideas markets function properly.

Similarly, if start-ups do have an advantage in providing for a future set of innovations – to the extent that those innovations involve creative destruction of incumbency rents – competition that permits start-ups with those advantages to become incumbents may provide greater innovative returns than those that would be generated through licensing or cooperation that preserved the start-up as an innovative force.

These issues suggest that there may be important dynamic considerations that may qualify the strong predictions borne out in static analyses. For this reason, this paper revisits those key conclusions in an explicitly dynamic environment. In so doing, I build upon a tractable framework for exploring start-up or entrant innovation in the context of competitive interactions with an incumbent firm that was developed by Segal and Whinston (2005) – hereafter, SW. SW did not examine licensing or cooperative commercialisation and only considered competition and the effect of incumbent antitrust practices on rates of innovation.[2] In addition, SW assumed that the same firms would persist in the industry through successive waves of innovation; something I relax here.

Specifically, the model set-up here considers an environment where at any given point in time there are only two firms in the industry – an incumbent and an entrant. As in SW, an entrant today may become an incumbent tomorrow and vice versa. As the focus

[2] Other work on cumulative innovation similarly does not endogenise the commercialisation choices of start-ups (see, for example, the survey by Scotchmer, 2005).

here is on start-up commercialisation choices and innovative incentives, I follow SW in assuming only start-ups engage in innovative activities.[3] When an entrant innovates, if there is no licensing (i.e., cooperative commercialisation), it displaces the incumbent for the next generation of innovation. If there is licensing, the incumbent is not displaced and preserves its role.

A key set of parameters in the model considers the *dynamic capabilities* of the firms. SW assumed that, should an incumbent be displaced, then it, with certainty, becomes the entrant for the next generation. This can be interpreted as a strong form of dynamic R&D capabilities whereby a current incumbent has a significant advantage as an innovator towards the next product generation in that it preempts others from contesting the innovation market.

Here I relax this assumption by allowing that incumbent capability to range from non-existent (the incumbent cannot engage in future innovation at all) to strong as assumed by SW. In addition, because my model considers licensing whereby the incumbent is not displaced, I also consider entrant dynamic capabilities. That is, should an entrant license its innovation, there is some probability that it will preempt others in the innovation market. If this probability is high, the entrant is said to have strong dynamic capabilities. However, a case that will be of interest is where this probability is low and licensing results in start-up exit from future innovation. It is this possibility that permits the dynamic analysis of notions that licensing may involve start-ups 'selling their birthright' to future innovative rents.

With this framework I find that some important and subtle, dynamic effects that significantly qualify the intuition of static models of innovation. First, the returns from

[3] This can be relaxed and I do so in Section 5 below.

licensing are driven by immediate savings (avoiding duplication of complementary assets and dissipation of monopoly rents) but also by the value of incumbency. That value is itself endogenous in a dynamic environment and it is demonstrated that it can be sometimes lower under licensing than under competition; mitigating start-up innovative incentives in equilibrium. Nonetheless, it is demonstrated that when licensing is an equilibrium outcome, start-up innovation rates are higher when licensing is permitted than when it is not; confirming standard intuition.

However, a key finding here is that the gains from trade from licensing may not always be positive. In a situation where incumbents have strong dynamic capabilities but start-ups do not, licensing means that some future innovative rents are jointly forgone by the current incumbent and entrant in favour of future entrants. Instead, competition means that such rents (even if they are lower) are captured by current firms – as the entrant becomes the incumbent and the incumbent becomes the next entrant. Thus, both firms may find this mutually preferable to cooperative commercialisation. This captures some of the case-based intuition that dynamic capabilities may favour continued competition but also highlights some subtleties in how such capabilities generate this outcome.

The important implication of this is that there is no simple relationship between rates of innovation and commercialisation strategy because the latter itself depends on industry and firm characteristics. Thus, empirical researchers need to consider the nature of dynamic capabilities as important controls in understanding the association between innovation levels and commercialisation choice.

The paper proceeds as follows: in Sections 1 and 2, the basic model is introduced and the equilibrium under no licensing (or competition) is presented. Section 3 then considers the licensing case including a derivation of the licensing fee in a dynamic context. Importantly, this demonstrates that incumbency advantage – even if not forfeited in equilibrium – does impact on innovation benefits in this case and characterises the gains from trade from licensing. Section 4 then considers the impact on this on equilibrium innovation rates and also the relationship between those rates and dynamic capabilities. Section 5 considers the robustness of these results to incumbent innovation and more entrant competition. A final section concludes.

## 1. Model Set-Up

Here we consider a 'quality ladder' model of innovation that allows a transparent comparison between competitive and cooperative modes of commercialisation.

*Consumers*

Suppose there is a continuum of infinitely-lived consumers of measure 1. Each consumes a nonstorable and nondurable good. Research and development can result in improved product quality. A product of generation *j*, generates utility for all consumers of $v_j = v + \Delta \cdot j$.

*Firms*

At any time, there are two firms in the industry; an incumbent (*I*) and an entrant (*E*). Both discount the future at a rate, $\delta \in (0,1)$ and both face no production costs. If the current generation of the product is *j*, I assume that the *j*-2$^{th}$ generation is in the public domain and can be produced by any firm. The *j*$^{th}$ and *j*-1$^{th}$ generations are patented and can be produced by their patent-holder or licensee.[4] Clearly, if these are the same firm, then that firm can charge a price of $2\Delta$ to consumers and still capture the entire market. On the other hand, if they are not the same firm, then the leader (who holds the production rights to *j*) can serve the whole market for a price of $\Delta$; being constrained by competition from the holder of the production rights to the previous generation[5]

At any particular juncture, I distinguish between the current market (and technological) leader in the industry – the incumbent – and others – the entrant. An incumbent, by definition, holds the production rights (via patent or license) to the current ($j^{th}$) product generation. Moreover, in so doing, I assume that the incumbent has an advantage in commercialising the next generation of product ($j$+1). This is modeled by assuming that any entrant would have to incur sunk costs of $f$ in order to produce generation $j$+1. The basic idea is that the act of producing the $j^{th}$ product generation gives the incumbent a competency in producing the $j+1^{th}$ generation. However, that advantage can only be maintained if the incumbent continues to produce the current generation. If an entrant were to enter and sink costs $f$, that entrant would have the advantage for the next generation and the incumbent would lose any advantage – becoming just another entrant for any future competition. I assume that such entry is credible; $\Delta \geq f$ . As we will see, this creates a value for incumbency that impacts upon the nature of competitive dynamics.

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4 I assume, as do SW, that the patents of different generations do not infringe on one another.

5 In contrast, SW assume that the current technological (and market) leader is always different from the previous one and so that price charged is always $\Delta$.

It is assumed that only the entrant engages in innovation.[6] Let $\phi \in [0,1]$ be the R&D intensity – literally the probability that the entrant generates an innovation in the current period. $c(\phi)$ is the cost of R&D where $c(.)$ is a non-decreasing, strictly convex function.

*Dynamic Capabilities*

A novel feature of the model here is that I allow both for the possibility that following innovation a firm is present in the market during the development of the next generation and the possibility that they are not. As noted earlier, for most models of patent races and innovation, displaced incumbents exit the industry while for SW a displaced incumbent merely forgoes technological leadership; taking on the role of the entrant.

Here I nest both of these possibilities. I assume that following successful entrant innovation, with probability $\sigma_I \in [0,1]$, the incumbent becomes the entrant in the next generation. Otherwise, they exit the industry and a new firm takes on the role of the entrant. Similarly, in the model of licensing explored below, an entrant who innovates and then licenses to the incumbent, with probability $\sigma_E \in [0,1]$, continues in the industry. Otherwise, they exit and are replaced by a new entrant. As noted earlier, this provides a means of parameterising and modeling an innovator's 'birthright' to future innovative rents.

One interpretation of this is that a firm is likely to transition between product generations if it has a dynamic R&D capability. A firm's capabilities are usually defined

[6] This is also assumed by SW. This assumption is relaxed in Section 5 below.

in terms of their ability to deliver products of a certain quality and at a certain cost. This ability then defines the position within a competitive marketplace. Dynamic capabilities are a step beyond this and refer to a firm's ability to transition in a changing environment. For instance, Teece, Pisano and Shuen (1997) "define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments." (p.516)

In this paper, I examine how innovative capabilities impact upon the level of innovation achieved in an industry. In this respect, the model here examines successive generations of products in an industry where each generation's arrival depends endogenously on the resources directed towards innovation and R&D activities. A limited number of firms will have a capability to conduct innovation so as to develop the next product generation. Those capabilities may come externally – through entry. Alternatively, they might be developed internally by those who are currently innovating towards the next product generation. In this respect, a firm is said to have a dynamic capability if they are able to successfully engage in development of the product generations beyond that being developed today.

As will be demonstrated below, this set-up enables exploration of the role of dynamic capabilities in the innovation process as well as considering individual firm incentives to invest in such capabilities. Nonetheless, this is a 'high level' analysis in that I do not explore the sources of such capabilities nor take a view on how they are maintained (cf: Sutton, 2002).

*Timeline*

In each period, all entrants select their R&D intensity. Then nature determines who (if any) has innovated and who among that set is awarded a patent. The patent holder then faces a choice. It can enter into production of the product generation by sinking costs, *f*, or it can negotiate with the current incumbent.[7] I assume that such negotiations take the Nash bargaining form where the incumbent and entrant both have equal bargaining power.[8] In contrast, when licensing is not possible, the patent holder faces no choice and must enter. Following this, nature then decides whether the firm that does not hold patent production rights continues in the industry or not.

## 2. No Licensing Case

I begin with the case where licensing is simply not possible. In the infinite-horizon dynamic game, following SW, I confine our attention to stationary Markov perfect equilibria using SW's dynamic programming approach. For this purpose, let $V_I$ be the expected present value of profits of the incumbent firm at the beginning of any given period and $V_E$ those of any given potential entrant. Given that innovation results in entry, these values will satisfy:

$$V_I = (1-\phi)(\Delta + \delta V_I) + \phi \sigma_I \delta V_E \qquad \text{(VI)}$$

$$V_E = \delta V_E + \phi(\Delta - f + \delta(V_I - V_E)) - c(\phi) \qquad \text{(VE)}$$

[7] This is a common presumption in innovative industries; see Teece (1987).
[8] In a non-cooperative bargaining model, Gans and Stern (2000) show that this outcome is the upper bound on the entrant's bargaining power when IP protection is potentially weak and the incumbent can invest in 'work around' technologies.

for any given R&D intensity, $\phi$. Note that, following an innovation, the entrant continues in the industry by default (as the incumbent) while the incumbent may only with probability $\sigma_I$ continue in the industry.

The equilibrium level of R&D intensity is given by the following set of equations:

$$\phi \in \arg\max_{\varphi \in [0,1]} \left\{ \varphi(\Delta - f + \delta(V_I - V_E)) - c(\varphi) \right\}$$

Following SW, we let *W* denote the "innovation prize." In this case,

$$W = \Delta - f + \delta(V_I - V_E) \tag{IB}$$

so that an entrant is effectively solving in each period:

$$\phi \in \arg\max_{\varphi \in [0,1]} \left\{ \varphi W - c(\varphi) \right\} \tag{IS}$$

Given the convexity of *c*(.), this gives an "innovation supply" relationship between the quantity of R&D ($\phi$) and its price (*W*). As we will see, with all cases considered below, all that changes is how *W* is determined while the (IS) relationship itself is otherwise stable. The convexity of R&D costs means that $\phi$ is non-decreasing in *W*.

Solving (VI), (VE) and (IB) simultaneously, we have:

$$V_I = \frac{(1-\phi)(1-\delta(1-\phi))\Delta + \phi\sigma_I\delta\left(\phi(\Delta - f) - c(\phi)\right)}{\Lambda} \tag{VI-Comp}$$

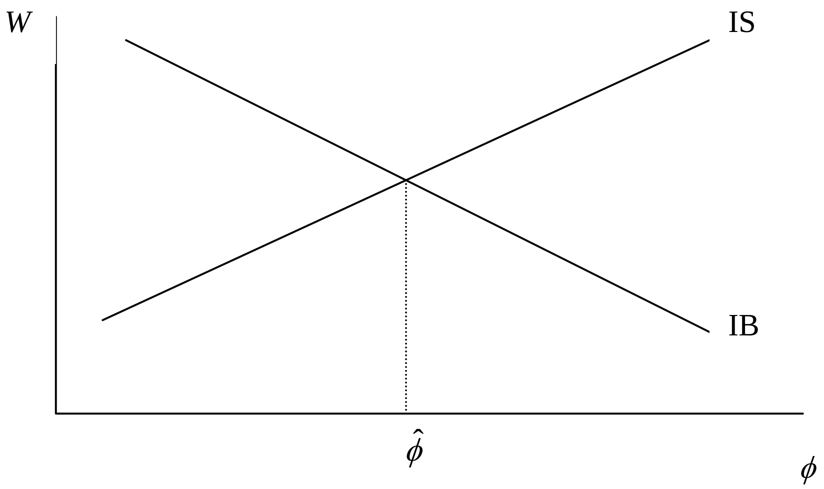
$$V_E = \frac{\phi\Delta - (1-\delta(1-\phi))\left(\phi f + c(\phi)\right)}{\Lambda} \tag{VE-Comp}$$

$$W = \frac{(1-\delta)\left(\Delta - f(1-\delta(1-\phi))\right) + \delta(1-\delta(1-\phi) - \phi\delta\sigma_I)c(\phi)}{\Lambda} \tag{IB-Comp}$$

where $\Lambda = (1-\delta(1-\phi))^2 - \sigma_I\delta^2\phi^2$. The last equation describes the "innovation benefit" relationship between R&D intensity and the level of the innovation prize (*W*). Any level of $\phi$ that jointly satisfies (IS) and (IB-Comp) is a stationary equilibrium of the R&D game.

Figure 1 depicts the equilibrium outcome.[9] The equilibrium rate of innovation, $\hat{\phi}$, occurs where the (IS) and (IB) curves intersect.[10] At this stage, it is useful to note that the equilibrium level of R&D will be non-decreasing in $\delta$, non-decreasing in $\Delta$, non-decreasing in $\sigma_I$ and non-increasing in *f*.[11] Basically, the first three changes cause the IB curve to shift outwards while the remaining change causes it to shift inwards. The IS curve is unchanged by another of these parameters.

**Figure One: Equilibrium under Competition**




[9] For convenience these are drawn as straight lines.
[10] The IB curve may not be monotonic. SW demonstrate, however, that the same qualitative analysis holds whether it is monotonic or not. For that reason, I simplify the graphical exposition for the more familiar downward sloping case.
[11] This can be seen by taking the derivative of *W* in (IB-Comp) with respect to each variable and applying Theorem 1 of Milgrom and Roberts (1994) on the corresponding set of equilibria.

The intuition for the comparative static on $\sigma_I$ is interesting. The more likely it is for the incumbent to persist in the industry, the higher is $V_I$. So long as $V_E > 0$, the possibility of persistence can only add to incumbent value. Similarly, the profits of both the entrant and the incumbent are discounted by their likelihood of persisting as an incumbent (the denominator in both VI-Comp and VE-Comp). This likelihood is increasing in $\sigma_I$ so $V_E$ rises as well. So an increase in $\sigma_I$ unambiguously raises the incumbency advantage ($V_I - V_E$) and hence the innovation benefit.

This means that, under competition, the more likely it is that an incumbent has a capability to innovate if displaced, the higher the rate of innovation will be in the industry. While it may appear at first glance that incumbents interested in slowing the rate of innovation – so as to preserve their incumbency for longer – may not wish this to happen, when they are the incumbent, it is better to have a capability than not. If it had to invest in that capability in each period, it would be willing to pay up to $\phi\delta V_E$ for the option. Note also that this incentive is even stronger if the entrant expects to make such an investment should it become the incumbent (as this has the indirect effect of increasing their rate of innovation).

## 3. Licensing and Cooperation

I now turn to consider licensing.[12] I will continue to assume here that entry is credible ($\Delta \geq f$). In this case, in negotiations with a patent holder, the incumbent earns $2\Delta - \tau + \delta V_I$ from licensing for a fee of $\tau$ but otherwise expects to earn $\sigma_I \delta V_E$ (as entry

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[12] As noted in the introduction, licensing is only one form of cooperative commercialisation. It fits the formal model and so I focus upon it here; commenting on differences with other forms of cooperation in the concluding section.

occurs and incumbency is lost). The innovator expects to earn $\tau + \sigma_E \delta V_E$ from licensing (as it may not persist in the industry) and $\Delta - f + \delta V_I$ otherwise (as it gains, with certainty, an incumbency advantage from entry).

There will be gains to trade through licensing if:

$$\underbrace{2\Delta - \tau + \delta V_I + \tau + \sigma_E \delta V_E}_{\text{Joint Payoff from Cooperation}} = 2\Delta + \delta(V_I + \sigma_E V_E)$$
$$\geq \Delta - f + \delta(V_I + \sigma_I V_E) = \underbrace{\sigma_I \delta V_E + \Delta - f + \delta V_I}_{\text{Joint Payoff from Competition}}$$

Note that cooperation avoids the dissipation of monopoly rents and the sunk costs of entry ($2\Delta - (\Delta - f)$). These are the same factors that drive the gains from trade for licensing in static models (see Salant, 1982; Gans and Stern, 2000).

However, here there is also a dynamic component to the joint surplus from licensing. First, a license agreement will allow the incumbent to preserve its profits and will preclude an entrant from capturing those profits. As there is only one incumbency rent, this nets out as a gain from trade from licensing.

This would also be the case for entrant profits if the incumbent and entrant had similar probabilities of continuing as an innovator. However, when these probabilities differ, licensing generates a gain to joint surplus of $(\sigma_E - \sigma_I)\delta V_E$. Notice that this may not be a gain at all if the probability that the entrant, as a licensor, continues to innovate towards the next generation is less than the probability that a displaced incumbent can do so; that is, if $\sigma_E < \sigma_I$. This might occur if the entrant has a more specialised focus on the current generation whereas the incumbent has capabilities that give it an R&D advantage in the next generation.

Take the extreme case where $\sigma_E = 0$ and $\sigma_I = 1$. By signing a licensing agreement, neither party earns $\delta V_E$ while by not signing the incumbent earns $\delta V_E$. In effect, the licensing agreement confers a *positive externality on a third party* (a potential entrant) which is internalised if no licensing agreement is reached. Indeed, if $\delta V_E > \Delta + f$, the overall gains from trade from licensing would not be positive and licensing would not occur. Instead, the competition case, as considered in the previous section would be the equilibrium outcome.

As $V_E$ is an endogenous variable, care must be taken to establish the existence of an equilibrium with licensing. Determining the conditions under which licensing will actually take place in equilibrium involves deriving the equilibrium value of $V_E$ under licensing which itself requires a solution for $\tau$. Given this, I employ the Nash bargaining solution to determine the license fee. Assuming for the moment, that the gains from trade are positive, let $\gamma \in [0,1]$ denote the bargaining power of the entrant. Then the license fee, $\tau$, is found by solving:

$$\max_{\tau} \left(2\Delta - \tau + \delta V_I - \sigma_I \delta V_E\right)^{1-\gamma} \left(\tau + \sigma_E \delta V_E - (\Delta - f + \delta V_I)\right)^{\gamma} \tag{1}$$

This gives $\tau = \Delta(1+\gamma) - f(1-\gamma) + \delta(V_I - (\sigma_E(1-\gamma) + \sigma_I \gamma)V_E)$.

In the licensing case, the (conjectured) equilibrium continuation payoffs are:

$$V_I = 2\Delta + \delta V_I - \phi\tau \tag{VI)’}$$

$$V_E = (1-\phi)\delta V_E + \phi(\tau + \sigma_E \delta V_E) - c(\phi) \tag{VE)’}$$

Notice that, along the (conjectured) equilibrium path, incumbency involves a continual flow of monopoly profits (2Δ) peppered by the payment of license fees to preserve technological (and market) leadership. In contrast, potential entrant returns are governed by the period earnings from license fees over the economic life of the patent.

In this case, the innovation prize is:

$$\begin{aligned} W &= \tau - (1-\sigma_E)\delta V_E \\ &= \Delta(1+\gamma) - f(1-\gamma) + \delta(V_I - (1+\gamma(\sigma_I - \sigma_E))V_E) \end{aligned} \tag{2}$$

Thus, as in the case of competition, under cooperation the (IB) curve includes a factor based on the value of incumbency. Even though this is never lost in (the conjectured) equilibrium, nevertheless, entrant innovators can still appropriate this in negotiations over the license fee.[13] The (IS) relationship remains the same as the no licensing case. As such, the equilibrium outcome will look qualitatively similar to Figure 1.

Solving for (VI)', (VE)' and *W* simultaneously gives:

$$V_I = \frac{\Delta\left((1-\delta(1-\phi))(2-(1+\gamma)\phi)-\delta\phi\left(2(\sigma_I-\sigma_E)\gamma+\sigma_E(1+\gamma)\phi\right)\right)-f(1-\gamma)\phi(1-\delta+(1-\sigma_E)\delta\phi)+(\sigma_I\gamma+\sigma_E(1-\gamma))\delta\phi c(\phi)}{\Lambda} \quad \text{(VI-Coop)}$$

$$V_E = \frac{\phi\left(2\Delta-(1-\gamma)(1-\delta)(\Delta+f)\right)-(1-\delta(1-\phi))c(\phi)}{\Lambda} \quad \text{(VE-Coop)}$$

$$W = \frac{(1-\delta)\left(2\Delta-(1-\gamma)(1-\delta)(\Delta+f)\right)+\delta\left((1-\delta)(1+(\sigma_I-\sigma_E)\gamma)+\delta\phi(1-\sigma_E)\right)c(\phi)}{\Lambda} \quad \text{(IB-Coop)}$$

where here $\Lambda = (1-\delta(1-\phi))^2 - \sigma_E\delta^2\phi^2 + \gamma(\sigma_I - \sigma_E)(1-\delta)\delta\phi$.

We are now in a position to characterise (partially) the equilibrium outcome.

***Proposition 1.*** *Licensing is an equilibrium outcome for (i) $\sigma_E \geq \sigma_I$ or (ii) $\delta$ sufficiently small. As $\sigma_I - \sigma_E$ and $\delta$ each approach 1, licensing is not an equilibrium outcome and competition is the equilibrium outcome.*

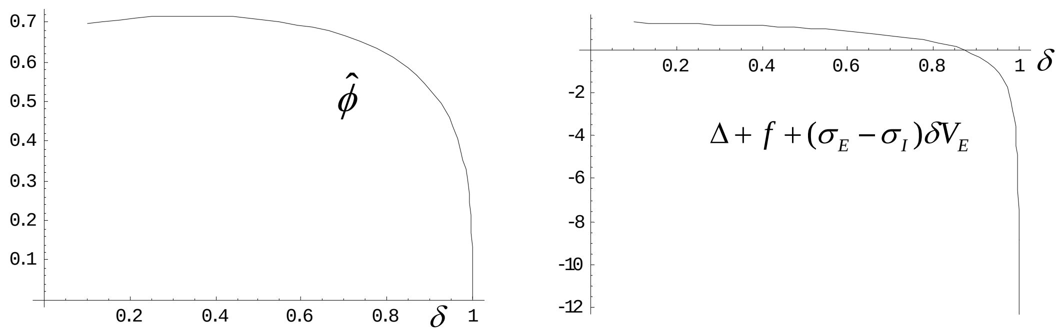
The proof is in the appendix. The first sufficient condition (i) re-states our earlier conclusion that the gains from trade are positive in that case. The second considers the

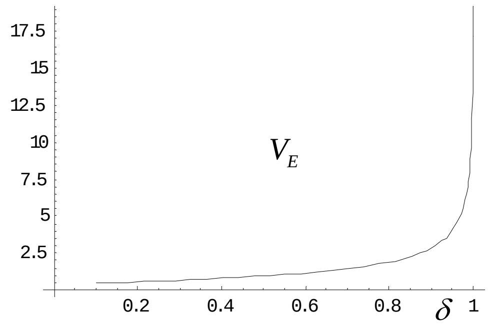
[13] Of course, this would not be possible if product market entry were not credible. Note, however, this does not require the innovator to exercise this entry option, merely to facilitate it (see also Anton and Yao, 1994).

alternative case and the proof demonstrates that, taking into account the endogeneity of $V_E$, as $\delta$ becomes small, the gains from trade continue to be positive. Put simply, the immediate return from cooperation (i.e., monopoly and saving duplicate sunk costs) is not outweighed by the loss of value from potential exit from the industry. However, as $\delta$ becomes large, we demonstrate that the gains from trade become negative (regardless of $\phi$) and so licensing is not an equilibrium outcome.

To provide some intuition for this result, it is useful to examine how the key variables of $\phi$, $V_E$ and the gains from trade change with respect to $\delta$ in a numerical example. Figure 2 plots these for fixed parameters as specified. Note that as the discount rate rises the equilibrium level of $\phi$ rises and then falls dramatically. This raises $V_E$ as the expected life of an innovation (if it is generated) rises and this increases licensing revenues to an entrant. However, the gains from trade from licensing decline for that same reason as those increased revenues are accrued by a firm other than the current incumbent and entrant. If $\sigma_E > \sigma_I$, the equilibrium level of innovation and $V_E$ have the same qualitative relationship with $\delta$ as in Figure 2 but the opposite implication for the gains from licensing as these additional rents are captured by current firms.

**Figure 2** ($c(\phi) = \phi^2$, $\Delta = 1$, $f = 0.3$, $\gamma = 0.5$, $\sigma_I = 0.8$, $\sigma_E = 0.2$)






Finally, it is worthwhile to note the role played by the bargaining parameter, $\gamma$. As noted in the introduction, it is sometimes suggested that start-ups should not consider licensing when they are weak negotiators. Proposition 1 demonstrates that this is not decisive as the gains for trade can be positive even where $\gamma = 0$. In this case, $\tau = \Delta - f + \delta V_I - \sigma_E V_E$ as the entrant is compensated for incumbency rents. Note that as $\gamma$ rises, $V_I$ falls while $V_E$ rises but this effect is outweighed by the increased current rents captured by the entrant. Thus, so $\tau$ and $W$ rise as well.

Interestingly, as $\gamma$ approaches 1, the value of incumbency does not fall to zero. Even where $\sigma_I = 0$ and the incumbent has no outside option, $V_I = 2\Delta \frac{1-\phi}{1-\delta(1-\phi)} > 0$. The incumbent captures rents because when evaluated prior to an innovation taking place, the incumbent earns $2\Delta$ for each period until that occurs. As soon as an innovation is generated, the entrant captures all of the on-going rents. Thus, observationally, incumbent cash flows are positive with occasional investments in licensing innovations. Nonetheless, as $\gamma$ approaches 1, $V_E > V_I$ so it is in fact more profitable to be an innovating entrant than an incumbent; that is, there is no incumbency advantage.

## 4. Innovation Rate and Commercialisation Strategy

We are now in a position to consider innovation rates across industries and their relationship to choices of cooperative and competitive commercialisation strategies. Not surprisingly, as that choice is itself contingent upon then nature of incumbent and entrant dynamic capabilities, in the absence of a control for such capabilities, there may be no consistent relationship between commercialisation strategy and the rate of innovation.

To demonstrate this, I will proceed in steps. First, I will examine the impact of licensing on innovation rates controlling for capabilities. Second, I will consider innovation rates as a function of capabilities taking into account the endogenous choice of commercialisation strategies. In so doing, the aim is to produce a set of theoretical predictions regarding the drivers of innovation across industries contingent upon various controls empirical researchers may have available.

*The impact of licensing on innovation*

Here I will abstract away from differences in capabilities and examine when happens to innovation rates as we move from a competitive to cooperative commercialisation pattern. This can be seen as providing an analysis of inter-industry differences where factors other than capabilities (e.g., the strength of IP protection) account for variation in commercialisation strategy or alternatively where capability variations can be otherwise taken into account. As such, I will assume, for the moment, that $\sigma_I = \sigma_E$ so as to simplify notation but also consider a situation where there are gains from trade from licensing (as in Proposition 1).

The framework provided here provides a simple means of characterising equilibrium rates of innovation. Given the upward sloping (IS) curve, that the rate of innovation will be higher where the prize (*W*) is higher. That is, licensing will result in a higher innovation rate if *W* as defined by (IB-Coop) is higher than that defined by (IB-Comp) for any given level of $\phi$.

In comparing (IB-Coop) with (IB-Comp), there are two factors to consider: the immediate benefit from the current innovation and the on-going benefit from an incumbency advantage. Under licensing, the immediate benefit from the current innovation is $(1+\gamma)\Delta-(1-\gamma)f$ whereas the returns from entry under no licensing are $\Delta-f$. These are only equivalent if $\gamma=0$. Thus, an innovator is able to gain more value under licensing because it is able to threaten the incumbent with the loss of monopoly profits and appropriate these without incurring sunk entry costs. In effect, the license fee is a share of the sum of industry profits under monopoly ($2\Delta$) and those under entry ($\Delta-f$) whereas under no licensing the innovator appropriates all of industry profits under entry. As industry profits under monopoly exceed those following entry, the prize under licensing is higher.

Countering this are future benefits. When $\sigma_I=\sigma_E$, under both licensing and no licensing, the innovator appropriates the incumbency advantage ($V_I-V_E$) less some share of the value from entry ($V_E$). However, for any given $\delta$, that advantage maybe greater under no licensing than it is under licensing. To see this, note that:

$$V_I-V_E=\frac{(1-\delta)\left(\Delta(1-2\phi)+\phi f\right)-(1-\sigma_I)(\Delta-f)\phi^2\delta+(1-\delta-\delta\phi(1-\sigma_I))c(\phi)}{(1-\delta(1-\phi))^2-\sigma_I\delta^2\phi^2} \quad \text{(IA-Comp)}$$

$$V_I-V_E=\frac{(1-\delta)2\left(\Delta-\phi(\Delta(1+\gamma)-f(1-\gamma))\right)-(1-\sigma_I)\delta\phi^2(\Delta(1+\gamma)-f(1-\gamma))+(1-\delta-\delta\phi(1-\sigma_I))c(\phi)}{(1-\delta(1-\phi))^2-\sigma_I\delta^2\phi^2} \quad \text{(IA-Coop)}$$

It is easy to see that (IA-Comp) will exceed (IA-Coop) if:

$$\begin{aligned}&(1-\delta)2\left(\Delta-\phi(\Delta(1+\gamma)-f(1-\gamma))\right)-(1-\sigma_I)\delta\phi^2(\Delta(1+\gamma)-f(1-\gamma))\\&>(1-\delta)\left(\Delta(1-2\phi)+\phi f\right)-(1-\sigma_I)(\Delta-f)\phi^2\delta\\&\Rightarrow\Delta(1-\phi 2\gamma)+\phi f(1-2\gamma)>\gamma(1-\sigma_I)\delta\phi^2(\Delta+f)\\&\Rightarrow\Delta+\phi f>\left((1-\sigma_I)\delta\phi+2\right)\gamma\phi(\Delta+f)\end{aligned}\tag{3}$$

However, this will not hold for all parameter values. The effective discount on that advantage is determined in the same way under both cases as is the desire to avoid R&D costs if forced to become an entrant ($c$). However, the advantage is also driven by the consequences of entry. In the no licensing case, this is the expected immediate return to entry ($\phi(\Delta-f)$) whereas in the licensing case, this is the fact that successful innovation causes the entrant to earn a license fee and for the incumbent to forgo that license fee. This has a net impact of $\phi(3\Delta-f)$ on the incumbency advantage. In effect, the returns to an entrant are higher under licensing and hence, the relative value of incumbency may be lower.

The discount rate weights these two effects. (IB-Coop) exceeds (IB-Comp) if:

$$\frac{(\Delta+f)\gamma(1-\delta)+\delta(\Delta+\phi f)}{1+2\delta(1-\phi)-\delta^2(1-2\phi-(1-\sigma_I)\phi^2)}\geq 0\tag{4}$$

Not surprisingly, when there is complete discounting ($\delta = 0$), it is clear that $W$ is higher when licensing occurs. When there is no discounting, maximum weight is placed on the incumbency advantage in the prize. However, even in this case, the difference between (IB-Coop) and (IB-Comp) becomes 0. The following summarises this result:[14]

***Proposition 2.*** *When $\sigma_I=\sigma_E$, the equilibrium innovation rate is higher under licensing than no licensing.*

[14] The qualifier is made only for notational simplicity. Whenever, licensing is an equilibrium outcome this the proposition holds.

Basically, the marginal improvement in the incumbency advantage under no licensing never outweighs the immediate benefits from licensing the current innovation.

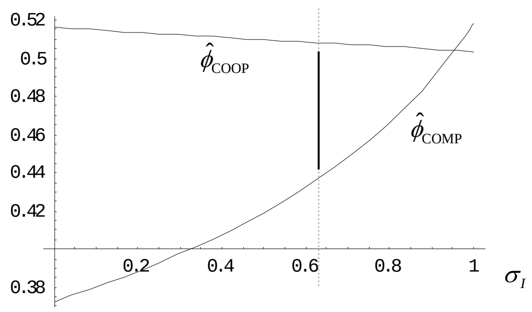
*Capabilities and innovation*

We now turn to consider the relationship between dynamic capabilities and the equilibrium rate of innovation. In Section 3, it was noted that the equilibrium rate of innovation under competition rose with $\sigma_I$; the probability that a displaced incumbent would become an innovating entrant in the next generation. By contrast, under licensing, incumbent dynamic capabilities are negatively related to equilibrium innovation rates. While an increase in $\sigma_I$ increases $V_I$ it reduces the gains from trade through licensing as it improves the incumbent's outside alternative. This has a direct and negative impact on the license fee and overall a negative impact on (IB-Coop).

When the choice of commercialisation strategy is endogenous, what then happens to innovation rate as the incumbent capability ($\sigma_I$) becomes stronger? As noted earlier, ceteris paribus, as $\sigma_I$ rises the commercialisation regime can switch from licensing to competition. Over the range where licensing is an equilibrium, innovation rates will fall with $\sigma_I$ only to rise again when competition is the equilibrium outcome. Thus, there is a broad U-shaped relationship between incumbent dynamic capabilities and innovation rates in an industry.

Figure 3 illustrates this for our numerical solution. In this example, the commercialisation regime moves from licensing to competition as $\sigma_I \gtrsim 0.6$. Notice that the innovation rate declines and then takes a discrete downward jump as we move from licensing to competition. The jump at this point is consistent with Proposition 2. The innovation rate then rises again and when $\sigma_I = 1$ (for this example) actually exceeds the rate when $\sigma_I = 0$.

**Figure 3 (**$c(\phi) = \phi^2$**,** $\Delta = 1$**,** $f = 0.3$**,** $\gamma = 0.5$**,** $\delta = 0.9$**,** $\sigma_E = 0$**)**




For entrants, dynamic capabilities only matter under licensing. Under competition, successful entrants become the incumbent and so they automatically persist for the next wave of innovation. In contrast, should licensing take place, greater entrant capabilities improve the probability that the entrant is the leading innovator of the next of generation (that is, $\sigma_E$). Moreover, that probability positively impacts upon both the likelihood that licensing takes place, the license fee negotiated (as it is part of the entrant's outside option), and also the chances that successful innovation will not drive the entrant from the industry. All of these combine to increase (IB-Coop) and so the equilibrium rate of innovation, under licensing is increasing in $\sigma_E$.

What this means is that as $\sigma_E$ rises, the commercialisation regime may switch from competition to cooperation and the equilibrium rate switch from a constant level (unrelated to $\sigma_E$) to a discrete jump upwards and a steady rise thereafter. As such, in contrast to the situation with incumbent capabilities, there is a monotonically increasing relationship between entrant capabilities and the rate of innovation.

## 5. Extensions

The above analysis assumes that (i) the number of active firms in an industry is always two and (ii) that, at any time, there is only one firm innovating in the industry. In this section, these assumptions are relaxed. First, there could be more than a single entrant and each competes to become the patent-holder of the next generation of product. Second, the incumbent might engage in innovation towards the next generation.

The purpose here is to analyse the impact of these changes on the two key conclusions reached above regarding the gains from trade from licensing and the relationship between commercialisation strategy and innovation rates of start-ups. It should be clear that by adding more innovators, the innovative capacity of the industry rises and the overall rate of innovation will rise too. My focus in this paper is not on this issue but on the gains from trade from licensing and on the incentives for start-ups to engage in innovative activity. As such, I will not fully characterise equilibrium outcomes here but focus instead on the robustness of previous results.

In order to consider this, I will continue to assume that if only a single firm generates an innovation in period, that firm becomes the patent-holder and in subsequent periods all innovation is directed towards the new generation. However, if more than one firm generates an innovation, I assume that the patent-holder is selected at random from amongst them. Let $\mathbf{\Phi}$ be the vector of innovation rates chosen by all firms including the incumbent and $N$-1 entrants. For entrant $i$, who chooses an innovation rate $\phi_i$, let $r_i(\mathbf{\Phi})$

be the probability that it receives the patent, conditional on generating an innovation. For example, if all $N$ firms choose the same innovation rate, $\phi$, and the patent-holder is chosen at random amongst successful innovators, then SW show that:

$$r(\phi)=\sum_{i=1}^{N}\tfrac{1}{k+1}\binom{N-1}{k}\phi^{k}(1-\phi)^{N-1-k}=\frac{1-(1-\phi)^{N}}{\phi N} \qquad (5)$$

For entrant $i$, the probability of winning an innovation prize ($W$) – be it incumbency or a licensing agreement – becomes $\phi_i r_i(\mathbf{\Phi})$. That innovation prize, $W$, is still determined by (IB) and (IB)' while (IS) is determined by:

$$\max_{\varphi} \varphi r_i(\mathbf{\Phi})W - c(\varphi) \qquad (6)$$

As innovation within a generation is 'memory less' (that is, has the same productivity from one period to the next), all that has changed here is the (IS) curve. Note that $r_i$ is non-increasing in the innovation rates chosen by others. Thus, the rate of innovation for a given start-up falls with $N$ and innovation rates chosen by entrants are strategic substitutes.

The gains from trade from licensing continue to be of the form: $\Delta + f + (\sigma_E - \sigma_I)\delta V_E$ although $V_E$ has fallen.[15] This would appear to mean that the likelihood that licensing does not take place has fallen. However, if $\sigma_E$ and $\sigma_I$, were adjusted to consider capabilities that generate an advantage over existing start-ups – say improving the probability of obtaining a patent $r_i(\phi)$, then the same considerations that

[15] Here I am implicitly assuming that only the entrant who is the patent-holder has an opportunity to continue innovating if licensing takes place. That is, for symmetric $\phi$, (VE) and (VE)' become:

$$V_E = (1-\phi)^N \delta V_E + \phi r(\phi)(\Delta - f + \delta V_I) - c(\phi) \qquad \text{(VE)}$$

$$V_E = (1-\phi)^N \delta V_E + \phi r(\phi)(\tau + \sigma_E \delta V_E) - c(\phi) \qquad \text{(VE)'}$$

It could be that all entrants or those who have made a discovery (even if it is not patented) have a dynamic capability. However, while adding complexity, this would not change the basic robustness of the results here.

drove licensing in the single entrant discussion will continue to do so when there are many innovators.

When the incumbent has the opportunity to innovator – either defensively or offensively – this will improve $V_I$. This, in turn, will spur innovation under competition (holding the strategic effect of incumbent innovation fixed) and hence, stimulate innovation incentives. As such, it is possible that entrant and incumbent innovative activities could be strategic complements. Thus, the simple comparative statics on innovation rates explored earlier could be more complex once these strategic interactions are taken into account. Nonetheless, at a first order, the relationships explored earlier are robust to these changes.

## 6. Conclusion and Future Directions

This is the first paper to consider the choice of start-up commercialisation strategy in a dynamic environment. It was demonstrated that dynamic considerations impact upon this decision in a way not captured by a purely static focus. In particular, the on-going roles of the parties of a licensing deal matter in terms of rent capture and the returns to licensing over competition. In turn, these on-going roles are related to dynamic capabilities – that is, the probability that a firm will have an innovative advantage in research towards the next generation of product based on its current role (as entrant or incumbent). These capabilities feedback to determine the general relationship between commercialisation activities of start-ups and their share of innovation across industries.

There are several directions in which the results of this paper could be extended and explored in future research. First, the model here considered licensing as the form of cooperative commercialisation. That had the feature that the assets and capabilities of start-ups were not acquired by the incumbent and could continue as an independent innovative entity for future research. Acquisition, as an alternative mode of start-up commercialisation, would integrate those assets and capabilities; adding a layer of complexity beyond the model here. Nonetheless, what the model here highlights is that the differing dynamic impacts of alternative modes of cooperative commercialisation will be important.

Second, in this paper, dynamic capabilities were considered exogenously. Either firms had them (to a certain degree) or they did not. In reality, the acquisition of such capabilities are likely to be a key and on-going strategic choice for firms. Thus, endogenising this choice and relating those capabilities to more fundamental market conditions (as in Sutton, 2002) would appear to be a promising avenue for future research. The model here provides a framework upon which such an extension might be based.

Finally, this model shares with many others a simple consideration of innovative strategy – namely, innovative intensity. Recent work by Adner and Zemsky (2005) goes beyond this to consider impacts on other strategic variables such as prices, market monitoring, firm size and the rate of overall technological progress. Their model is dynamic but does not consider the choice of commercialisation strategy – it only considers a competitive route for start-ups. Linking their approach with the endogenous choice of commercialisation strategy as considered here may lead to a richer picture of the innovation environment and the role of displacing or disruptive technologies on market and technological leadership in an industry.

## Appendix: Proof of Proposition 1

Note first that, in equilibrium, $V_E \geq 0$, as an entrant could always guarantee itself at least 0 by setting $\phi = 0$. In equilibrium, the gains for trade from licensing, $\Delta + f + (\sigma_E - \sigma_I)\delta V_E$, are:

$$\Delta + f + \delta(\sigma_E - \sigma_I)\frac{\phi\left(2\Delta - (1-\gamma)(1-\delta)(\Delta + f)\right) - (1-\delta(1-\phi))c(\phi)}{\Lambda} \qquad (7)$$

This is clearly positive if $\sigma_E \geq \sigma_I$. If we take the limit as $\delta$ approaches 0, we get $\Delta + f > 0$.

Setting $\sigma_I = 1$ and $\sigma_E = 0$, (7) becomes:

$$\Delta + f - \delta\frac{\phi\left(2\Delta - (1-\gamma)(1-\delta)(\Delta + f)\right) - (1-\delta(1-\phi))c(\phi)}{\Lambda} \qquad (8)$$

where $\Lambda = (1-\delta(1-\phi))^2 + \gamma(1-\delta)\delta\phi$. We wish to prove that this is negative as $\delta \to 1$. Suppose not, then (8) being positive is equivalent to:

$$(\Delta + f)\Lambda \geq \delta\phi\left(2\Delta - (1-\gamma)(1-\delta)(\Delta + f)\right) - (1-\delta(1-\phi))c(\phi) \qquad (9)$$

Taking limits on both sides, we obtain:

$$(\Delta + f)\phi \geq 2\Delta - c(\phi) \qquad (10)$$

Which cannot hold as

$$\lim_{\delta\to 1} V_E \geq 0$$
$$\Rightarrow \lim_{\delta\to 1} \phi\left(2\Delta - (1-\gamma)(1-\delta)(\Delta + f)\right) - (1-\delta(1-\phi))c(\phi) \geq 0$$
$$\Rightarrow \phi(\Delta - f\phi - c(\phi)) \geq 0$$

If this holds, (10) cannot hold; a contradiction. Therefore, licensing is not an equilibrium outcome in this case.

We still need to show that competition is an equilibrium outcome. That is, starting from a competitive equilibrium, in any period, do an incumbent and entrant have an incentive to deviate for one period and license? Setting $\sigma_I = 1$ and $\sigma_E = 0$ and utilising (VE-Comp), the gains from trade from licensing when competition is expected are:

$$\Delta + f - \delta\frac{\phi\Delta - (1-\delta(1-\phi))\left(\phi f + c(\phi)\right)}{\Lambda} \qquad (11)$$

where $\Lambda = (1-\delta(1-\phi))^2$. This will be positive if:

$$(\Delta + f)\Lambda \geq \delta\left(\phi\Delta - (1-\delta(1-\phi))\left(\phi f + c(\phi)\right)\right) \qquad (12)$$

Taking limits this will hold if: $f\phi \geq \Delta - c(\phi)$ . However, as above, it is straightforward to show that $\lim_{\delta \to 1} V_E \geq 0 \Rightarrow \phi(\Delta - f\phi - c(\phi)) \geq 0$; a contradiction with (12). Thus, the gains from licensing are negative and competition is an equilibrium outcome.

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