October, 2007

Start-Up Commercialisation Strategy and Innovative Dynamics

Joshua S Gans

Start-Up Commercialisation Strategy and Innovative Dynamics*

by

Joshua S. Gans
University of Melbourne

First Draft: 15th December, 2005
This Version: 22nd October, 2007

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: O31.

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

---

* I thank Nisvan Erkal, Thomas Hellmann, Yossi Speigel, Scott Stern, and participants at the NBER Entrepreneurship Strategy and Structure Conference (Jackson, WY, 2007), the Australasian Econometric Society Meetings (Alice Springs, 2006), 2007 IIO Conference (Savannah, GA) and University of Virginia for helpful discussions and the Intellectual Property Research Institute of Australia (IPRIA) and an ARC Discovery Grant for financial assistance. Responsibility for all errors lies with me. All correspondence to Joshua Gans, Melbourne Business School, 200 Leicester Street, Carlton VIC 3053 Australia, E-mail: J.Gans@unimelb.edu.au. The latest version of this paper is available at www.mbs.edu/jgans.

Entrepreneurs rarely continue to manage the firms they found; exiting through acquisition or perhaps through on IPO that dilutes their control. As is well known, these modes of exit have very different properties. Specifically, start-ups might *compete* head-to-head with incumbents in product markets with an IPO cementing that independence. Alternatively, they might *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 (2006) who also considered the 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. An implication of this is that the share of

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

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 too early and losing their 'birthright' to future innovative returns (Bartlett, 1983; Cape, 1999) or otherwise "mortgaging away" their company's future (Pisano, 1994, p.10). These cases hypothesise that, when a start-up firm has opportunities for developing innovations in the future, by cooperating with incumbents today, those opportunities are potentially diminished. Indeed, the participants in the cases appear to suggest that this future cost may be so great that a start-up firm should consider avoiding licensing and cooperation altogether.

To an economist, such possibilities are generally seen as being another factor in the price of cooperation: namely, a start-up firm would have to be compensated for any reduction in its ability to innovative in the future. However, even recognising this, it may be that the gains to trade between established firms and start-ups are low or negative when the impact of future innovative competition is taken into account. Therefore, to properly take these considerations into account requires a dynamic model; the provision of which is the contribution of this paper.

To achieve this, 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 (2007) – hereafter, SW. SW only examined a limited form of licensing 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 (effectively) at most two firms in the industry – an incumbent and an entrant.[3] As in SW, an entrant today may become an incumbent tomorrow and vice versa. As the focus here is on start-up commercialisation choices and innovative incentives, I focus on a model where the start-up's choice of innovation is endogenous. However, unlike SW, I also allow incumbents to assume an innovation leadership role (although their innovation intensity is treated as exogenous for tractability reasons). When an entrant innovates, if there is no cooperation (i.e., licensing or acquisition), it displaces the incumbent for the next generation of innovation. If there is cooperation, 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-

---

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

[3] In actuality, the model explicitly allows for many firms and this is critical to the analysis and conclusions. However, through simplifying assumptions I derive a situation where consideration is required of only two firms at any given stage of the dynamic game.

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 cooperation results in low prospective returns for the start-up from future innovation. It is this possibility that permits the dynamic analysis of notions that licensing or acquisition may involve start-ups ‘selling their birthright’ to future innovative rents. In essence, I allow the commercialisation decision to impact both on the type of competition in product markets today as well as the structure of competition in innovation markets in the future. This highlights a dual impact from commercialisation choices.

This modification reflects reality. Specifically, there are many instances where future innovative potential rests with those who have innovated in the present. For instance, Niklas Zennstrom and Janus Friis founded the peer-to-peer file sharing network, KaZaA, which was acquired by Sharman, before moving onto found the peer-to-peer IP telephony network, Skype, which itself was acquired by eBay. They have now moved into IP television with a new venture, Joost. In each case, they have leveraged skills to become a lead innovator in the next generation of peer and fast transfer Internet technologies.

In other cases, the leverage of dynamic capabilities has led to direct competition for the initial venture. Steve Jobs founded Apple in the 1970s but left in 1986 following disagreements on firm direction to found NeXT and Pixar. Ten years later NeXT was acquired by Apple with its operating system to become the core of the highly successful OSX. Pixar was acquired by Disney in 2006. Similarly, Walt Disney, having been rebuffed and seen his animation ideas expropriated by several studios, went on to found his own company and dominate the entire industry (Gabler, 2006). In contrast to Jobs (whose technologies and skills was acquired), Disney was to use his dynamic capabilities to take on established firms in the product market and himself become the market leader.

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 licensing are driven by immediate savings (avoiding duplication of complementary assets and dissipation of monopoly rents) but also by the value of incumbent technological leadership. 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 the dynamic capabilities are very asymmetric, licensing means that some future innovative rents are jointly forgone by the current incumbent and entrant in favour of future entrants. In contrast, 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, depending upon the relative dynamic capabilities, 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 analyses acquisition as opposed to licensing as a form of cooperative commercialisation. It is demonstrated that these modes have distinct dynamic differences. Highlighting those is a separate contribution of the paper. Section 5 then considers the impact of licensing on equilibrium innovation rates and also the relationship between those rates and dynamic capabilities. A final section concludes.

1. Model Set-Up

The basic set-up of the model follows SW but with an important generalisation. Whereas SW assume that a displaced incumbent becomes an innovating entrant with certainty, here I allow for a more competitive structure to entrant innovative activity. As I describe below, it is no longer certain that a displaced incumbent will become the innovating entrant and, also, as this matters when considering cooperative commercialisation, an entrant cannot be guaranteed a role as an innovating entrant in the future.

Firms and Innovations

The model involves discrete time and an infinite horizon with the common discount rate for all participants of $\delta \in [0,1]$. Innovations occur sequentially with each innovation being a new product that yields valuable quality advantages over the previous generation. The firm that develops the innovation receives an infinitely lived patent on it; although the expected economic life of the product will be finite. At any given point in time, there is one firm, the incumbent (*I*), who holds the patent rights to the current leading product or generation. Apart from the first period, the product generates a constant flow of monopoly rents, Π, until such time as it is displaced by a new innovation.

While SW assumed that only an entrant firm would expend resources on innovation, here it is assumed that there is a pool of firms (infinite in number) and including the current incumbent that could potentially engage in innovative activity. When it is the current incumbent, innovation for them carries an additional short-term profit reward, Δ, that they earn in the period they innovate.

I depart from SW by also allowing for the possibility that it is the incumbent and not an entrant who takes the leadership in innovation. Following O'Donoghue, Scotchmer and Thisse (1998), I assume that only one of these (to be termed 'the entrant' or *E* if it is not the current incumbent, *I*) is selected at random with the capability to invest in research resources towards that next generation. This firm is the *innovation leader*. One can conceptualise this situation as one where ideas for the next product generation occur at random and are granted to only one firm who then chooses the level of resources to invest towards realising it as a viable innovation. Therefore, for any given firm, the probability that they will engage in innovative entry is infinitesimal. However, as I discuss below, for existing participants in the industry, I consider what happens when they have an advantage in being selected as the *innovation leader*. As noted earlier, this will be a departure from SW's assumption where an incumbent becomes the next innovative entrant with certainty.

In each period, the innovation leader, *i*, chooses its R&D intensity, $\phi_i \in [0,1]$ – literally the probability that it generates an innovation in the current period. $c(\phi_i)$ is the cost of R&D where *c*(.) is a non-decreasing, strictly convex function with $c(0)=0$.

In this set-up, an innovation leader who is an entrant has an incentive to engage in positive R&D effort as this can only lead to improved profits. However, for an incumbent innovation leader this may not be the case. Greater innovative effort may lead to a situation where their future incumbency is placed at risk (something that will become more explicit below). Clearly, if they set $\phi_I = 0$, then, should an incumbent become the innovation leader, no further innovation would occur in the industry as their position would be infinitely lived. This is an artifact of our assumption – made for simplification – that there is only one innovation leader at any particular moment. Clearly, if there was competition amongst more than one leader or some probability that the leader was displaced, this issue would not arise.

For simplicity, as the focus of this paper is on start-up entrepreneurial innovation and choices, I will adopt an assumption that there is a minimum level of R&D effort that an incumbent innovation leader must expend in order to retain their leadership. Moreover, given this, I will assume that conditions are such that (a) that minimum effort binds and so R&D effort is set at that point; which I will continue to notate as ϕ_I and (b) that the continuation profits of the incumbent at this minimum effort are positive (so a participation constraint is satisfied). Thus, for all intents and purposes, incumbent R&D effort, should it apply is treated *exogenously*. This assumption can be relaxed in various ways that add notational complexity but no additional insight with respect to the main results of the paper.

Commercialisation Choices

When a new product is generated by an entrant, the patent holder, *E*, faces a choice. It can enter into production of the product generation (competition) or it can negotiate with the current incumbent (cooperation).[4] Following this, Nature then decides whether the firm that does not hold patent production rights is selected amongst the pool of firms to become the next entrant.

If *E* chooses a competitive path, *I* loses its monopoly profits and for the next period both it and *E* earn profits of π, where $\pi \leq \frac{1}{2}\Pi$.[5] Entry into the product market costs sunk expenditures of *f*. I assume that such entry is credible; $\pi \geq f$. As we will see, this creates a value for incumbency that impacts upon the nature of competitive dynamics. Following that, if another innovation has not occurred, *E* assumes the role of *I* and earns a profit flow of Π. The previous incumbent then becomes one in the pool of firms from which the next entrant will be selected. *E* also has a chance of becoming the innovation leader but in the incumbent role. For simplicity, it is assumed that incumbent would have to sink costs, *f*, if it wished to re-enter the product market with a new future innovation.

Alternatively, if *E* engages in cooperative commercialisation it negotiates to sell *I* an exclusive license to its innovation.[6] I assume that such negotiations take the Nash bargaining

---

[4] This is a common presumption in innovative industries; see Teece (1987).

[5] SW assume that, in competition, *I* and *E* earn different profit levels. This is important to their analysis but as it plays no special role here, to save notation, I assume profit levels under competition are symmetric.

[6] It is implicitly assumed that if *E* were to engage in non-exclusive licensing, then the resulting on-going competition between two firms in product markets would be so intense as to make entry non-credible. Of course, licensing terms can be utilised to soften such competition. In this case, however, the profit impacts of an exclusive and non-exclusive license would be the same.

form where the incumbent and entrant both have equal bargaining power.[7] If a licensing deal is successfully negotiated, *E* receives a once-off payment, τ, while *I* preserves its monopoly position. A licensing agreement avoids the immediate competitive period between *E* and *I* and also the need for *E* to incur entry costs of *f*. In this situation, it is *E* who returns to the pool of firms as a potential future entrant while *I* has a chance of becoming the innovation leader as an incumbent.

Dynamic Capabilities

A novel feature of the model here is that the set of innovating firms can change from generation to generation. Specifically, I allow both for the possibility that, following a successful 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. Recall that, following successful entrant innovation, the next innovation leader is selected from an infinite pool of firms; including the displaced incumbent, in the case of competition, or the entrant, in the case of cooperation. However, there are distinct reasons why each might have a greater chance of being selected from that pool; that is, an advantage in future innovative competition.

For a previous incumbent who is not an innovation leader, knowledge of the industry may afford them with an advantage due to superior knowledge of the market and customers. This is a capability that arises as a result of being a producer. To capture this, I assume that

---

[7] 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.

following successful past innovation in the industry, with probability $\sigma_p \in [0,1]$, the incumbent becomes the innovation leader for the next generation (the subscript *p* here standing for innovative capabilities generated by virtue of being a *p*roducer). This might be as an incumbent or entrant depending upon whether cooperative commercialisation occurs or not. Otherwise, they (effectively) exit the industry and another firm takes on the role of the entrant.

For an entrant who pursues cooperative commercialisation, their future innovative advantage may arise because of their knowledge of the innovative process for this line of products. To capture this, I assume that an entrant who innovates, with probability $\sigma_i \in [0,1]$ (the subscript *i* here standing for innovative capabilities generated by virtue of being an *i*nnovator), becomes the innovation leader (again as an incumbent or entrant as the case may be). Otherwise, they exit and are, potentially, replaced by a new entrant. As noted earlier, this provides a means of parameterising and modeling an innovator's 'birthright' to future innovative rents. It captures the start-up's advantage in generating future innovations.

Finally, the previous incumbent might also be an innovation leader. In this case, they combine the knowledge from production and innovation and this translates into a probability, $\sigma_{ip} \in [0,1]$ that they will continue as the innovation leader for the next generation (the subscript *ip* here standing for capabilities generated by virtue of being both a producer and an innovator). This probability can also arise if an innovating entrant and a non-innovating incumbent were to integrate through an acquisition (rather than licensing).

One interpretation of these parameters 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 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).[8]

2. No Licensing Case

To provide a point of comparison with SW, I begin with the case where licensing is not possible. In the infinite-horizon dynamic game, following SW, I confine attention to stationary Markov perfect equilibria using SW's dynamic programming approach. For this purpose, let V_I

[8] It also does not take into account that the capability itself may be a function of commercialisation choices (e.g., that licensing might give a start-up cash to finance the next innovation generation).

be the expected present value of profits of a non-innovating incumbent firm at the beginning of any given period, V_I^i those for an innovating incumbent and V_E those of an innovating entrant. These values will satisfy:

$$V_E = (1-\phi_E)\delta V_E + \phi_E(\pi - f + \sigma_i \delta V_I^i + (1-\sigma_i)\delta V_I) - c(\phi_E) \qquad \text{(VE)}$$

$$V_I = (1-\phi_E)(\Pi + \delta V_I) + \phi_E(\pi + \sigma_p \delta V_E) \qquad \text{(VI)}$$

$$V_I^i = (1-\phi_I)(\Pi + \delta V_I^i) + \phi_I(\Pi + \Delta + \sigma_{ip}\delta V_I^i + (1-\sigma_{ip})\delta V_I) - c(\phi_I) \qquad \text{(VI-i)}$$

where ϕ_E is the R&D intensity chosen by an innovating entrant and ϕ_I is the R&D intensity chosen by an innovating incumbent. Note that, following an entrant innovation, the entrant continues in the industry by default (as the incumbent) while the incumbent may only with probability σ_p continue in the industry as an innovating entrant. In addition, with probability σ_i the new incumbent becomes an innovating one. If an incumbent generated the innovation, with probability σ_{ip} it continues as the innovator for the next generation.

As noted earlier, we treat incumbent R&D intensity as exogenous. For an entrant innovator, the equilibrium level of R&D intensity is given by the following set of equations:

$$\phi_E \in \arg\max_{\varphi \in [0,1]} \left\{ \varphi\Big(\pi - f + \delta\big(\sigma_i V_I^i + (1-\sigma_i)V_I - \phi_0 V_E\big)\Big) - c(\varphi) \right\}$$

Following SW, we let W_E denote the "innovation prize or benefit." In this case,

$$W = \pi - f + \delta\big(\sigma_i V_I^i + (1-\sigma_i)V_I - V_E\big) \qquad \text{(IB-Comp)}$$

so that an entrant is effectively solving in each period:

$$\phi_E \in \arg\max_{\varphi \in [0,1]} \{\varphi W - c(\varphi)\} \qquad \text{(IS)}$$

Given the convexity of $c(.)$, this gives an "innovation supply" relationship between the quantity of R&D (ϕ_E) 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 ϕ_E is non-decreasing in W.

The equilibrium level of R&D by E (should they have the opportunity), is determined by solving (VI), (VI-i) and (VE) simultaneously and using these to find the intersection of the (IB) and (IS) functions. The IB equation describes the "innovation benefit" relationship between R&D intensity and the level of the innovation prize. Any level of R&D intensity that jointly satisfies (IS) and (IB) is a stationary equilibrium of the R&D game. The expressions involved are not of direct interest and so are stated in the Appendix.

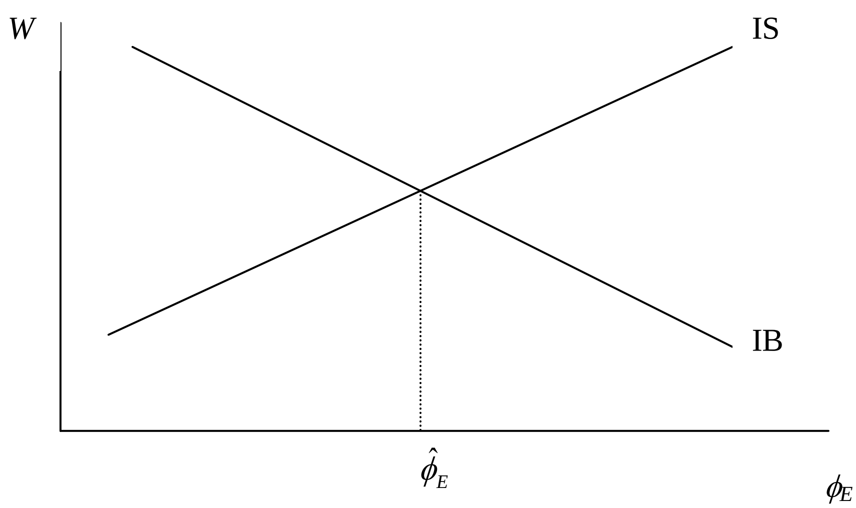
Figure 1 depicts the equilibrium outcome.[9] The equilibrium rate of innovation, $\hat{\phi}_E$, occurs where the (IS) and (IB) curves intersect.[10] At this stage, it is useful to note that the equilibrium level of R&D will be non-decreasing in δ, non-decreasing in Π, non-decreasing in σ_p and non-increasing 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.

The intuition for the comparative static on σ_p 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. This likelihood is increasing in σ_p so V_E rises as well. So an increase in σ_p unambiguously raises the

[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.

incumbency advantage ($V_I - V_E$) and hence the innovation benefit.

Figure One: Equilibrium under Competition



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 $\phi_E \delta V_E$ 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, $\pi \geq f$. In this case, in negotiations with a patent holder, the incumbent earns $\Pi - \tau + \sigma_p \delta V_I^i + (1-\sigma_p)\delta V_I$ from licensing for a fee of τ but otherwise expects to earn $\pi + \sigma_p \delta V_E$ (as entry occurs and incumbency is lost). The innovator expects to earn $\tau + \sigma_i \delta V_E$ from licensing (as it may not persist in the industry) and $\pi - f + \sigma_i \delta V_I^i + (1-\sigma_i)\delta V_I$ otherwise (as it gains, with certainty, an incumbency advantage from entry).

There will be gains to trade through licensing if:

$$\underbrace{\Pi - \tau + \sigma_p \delta V_I^i + (1-\sigma_p)\delta V_I + \tau + \sigma_i \delta V_E}_{\text{Joint Payoff from Cooperation}} \geq \underbrace{\pi + \sigma_p \delta V_E + \pi - f + \sigma_i \delta V_I^i + (1-\sigma_i)\delta V_I}_{\text{Joint Payoff from Competition}}$$
$$\Rightarrow \Pi - (2\pi - f) \geq \left(\sigma_i - \sigma_p\right)\delta\left(V_I^i - V_E - V_I\right) \tag{1}$$

Note that cooperation avoids the dissipation of monopoly rents and the sunk costs of entry; $\Pi - (2\pi - f)$. 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 $(\sigma_p - \sigma_i)\delta\left(V_I^i - V_E - V_I\right)$. Notice that this may not be a gain

---

[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.

at all if (i) the profits of an incumbent innovator are low; and (ii) 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 $\sigma_i < \sigma_p$. 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 $\sigma_i = 0$ and $\sigma_p = 1$ and where $V_I^i = V_I$. By signing a licensing agreement, neither party earns δV_E while by not signing the incumbent earns $\pi + \delta V_E$. 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 $\delta V_E > \Pi - 2\pi + f$, the overall gains from trade from licensing would not be positive and licensing would not occur.

As the continuation payoffs are endogenous, 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 continuation values under licensing which itself requires a solution for τ. 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, τ, is found by solving:

$$\max_\tau \left(\Pi - \tau + \sigma_p \delta V_I^i + (1-\sigma_p)\delta V_I - \pi - \sigma_p \delta V_E\right)^{1-\gamma} \left(\tau + \sigma_i \delta V_E - (\pi - f + \sigma_i \delta V_I^i + (1-\sigma_i)\delta V_I)\right)^{\gamma} \quad (2)$$

This gives $\tau = \Pi\gamma + (2\pi - f)(1-\gamma) + \delta V_I + \delta(\sigma_i(1-\gamma) + \sigma_p\gamma)(V_I^i - V_I - V_E)$.

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

$$V_I = \Pi + \delta V_I - \phi_E \left(\tau - \sigma_p \delta (V_I^i - V_I) \right) \quad \text{(VI)'}$$

$$V_E = (1-\phi_E)\delta V_E + \phi_E(\tau + \sigma_i \delta V_E) - c(\phi_E) \quad \text{(VE)'}$$

while the equation for V_I^i remains as in the competition case. Notice that, along the (conjectured) equilibrium path, incumbency involves a continual flow of monopoly profits (Π) peppered by the payment of license fees to preserve technological (and market) leadership. In contrast, potential entrant returns are governed by the periodic earnings from license fees over the economic life of the patent.

In this case, the innovation prize is:

$$W = \tau - (1-\sigma_i)\delta V_E \quad (3)$$

Thus, as in the case of competition, under cooperation the (IB) curve includes a factor based on the value of incumbency; though τ, even though this is never lost in (the conjectured) equilibrium. Nevertheless, entrant innovators can still appropriate part of this in negotiations over the license fee.[13] The (IS) relationship remains the same as the no licensing case. The appendix states the resulting equilibrium continuation values.

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

Proposition 1. *Licensing is an equilibrium outcome for δ sufficiently small and/or $\sigma_i - \sigma_p \approx 0$. Licensing is not an equilibrium outcome for δ sufficiently large as (i) $\sigma_p - \sigma_i \to 1$; or (ii) $\sigma_i - \sigma_p \to 1$.*

The proof is in the appendix. The proposition reflects what we found examining condition (1) but reveals an additional factor. Two things generate a situation where licensing is not an equilibrium. First, farsightedness (δ) whereby weight is placed on dynamic factors as opposed to static ones. Second, capability asymmetry whereby either the incumbent *or* the entrant has a

[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).

significantly large opportunity to be the lead innovator for the next generation (i.e., σ_i and σ_p are significantly different). Our analysis of (1) revealed only the role of a dynamic advantage to the incumbent. Closer examination also reveals that licensing is not an equilibrium when the entrant's dynamic advantage is large.

Intuitively, how this operates depends upon whether $V_I^i - V_E - V_I < 0$ or not. When $\sigma_i - \sigma_p$ is small, V_I^i is relatively small and so the value of one of them becoming an incumbent lead innovator is less than the sum of values from one of them becoming the entrant lead innovator. If σ_i is low while σ_p is high, those joint returns are improved by not licensing as this maximises the likelihood that one of them (in this case, the current incumbent) becomes an entrant lead innovator. In contrast, when $\sigma_i - \sigma_p$ is large, V_I^i is relatively large and so the goal would be to maximise the chances of one of the parties becoming an incumbent lead innovator. Note licensing will not achieve this when σ_i is high while σ_p is low as it is preferable for the start-up to become the incumbent.

At this point, it is instructive to return to the informal case-based argument that cooperative commercialisation may not be undertaken because the start-up innovator cannot be compensated for a loss of future innovative rents. The argument is that, by licensing, the start-up forgoes the incumbency position and the advantages that yields in future innovative competition. In our formal model here, this factor would be most salient when σ_i is high. When this is the case, an entrant who forgoes licensing has a good chance of becoming an incumbent who is the innovation leader.

However, Proposition 1 demonstrates that this informal argument does not drive competition in equilibrium. First, it is not simply that σ_i is large but that σ_i is large relative to

σ_p. Second, if σ_i is relatively large, by not licensing, the incumbent and entrant maximise the chance of realising the profits from an incumbent innovation leader. However, this is only mutually valuable in a situation where $V_I^i - V_E - V_I > 0$; so that industry profits are maximised by ensuring that an incumbent is the innovation leader. Proposition 1 tells us that when σ_i is relatively high, having an incumbent as the innovation leader does in fact maximise industry profits. Thus, in combination, a relatively high σ_i does lead to the parties avoiding licensing.

But Proposition 1 also demonstrates that the opposite can be the case. In a situation where σ_p is relatively large, it may not be mutually beneficial to agree to licensing. In this situation, $V_I^i - V_E - V_I < 0$, and so the parties would prefer a situation that leads to one of them becoming the next entrant. When σ_p is large, the incumbent forgoes become an innovation leader by not striking a deal with the start-up. Between them there is no loss and gain. In fact, it is *because licensing, in this case, benefits other potential entrants* that it may not be worthwhile.[14] In situations where $\sigma_p - \sigma_i$ is high, licensing means that, in the next round of the innovation game, the weaker competitor amongst *I* and *E* enters that game. In contrast, with no licensing, it is the stronger competitor that enters. Hence, there is a net loss from *I* and *E* to others if licensing occurs. Thus, claims for competitive commercialisation are supported but for different and more subtle reasons than is articulated in case analyses.

4. Licensing versus Acquisition

Licensing is not the only form of cooperative commercialisation strategy. Another commonly practiced situation involves the start-up being acquired by the incumbent firm;

[14] This also raises the possibility that if there were multiple incumbents, a similar external effect could arise. Multiple incumbents raise many other issues and so this possibility is left for future research.

perhaps in situations where a licensing agreement or shift in intellectual property rights is infeasible. The difference between acquisition and licensing is that the start-up is removed from the pool of potential innovators for the next generation. However, their capabilities are added to those of the incumbents. Consequently, this alters – from σ_i to σ_{ip} – the chance that the integrated start-up will become the innovator for that generation. Here, I consider when acquisition might be an equilibrium outcome relative to competition and also relative to licensing.

There will be gains from trade from acquisition rather than competition if:

$$\underbrace{\Pi-\tau+\sigma_{ip}\delta V_I^i+(1-\sigma_{ip})\delta V_I+\tau}_{\text{Joint Payoff from Cooperation}} \geq \underbrace{\pi+\sigma_p\delta V_E+\pi-f+\sigma_i\delta V_I^i+(1-\sigma_i)\delta V_I}_{\text{Joint Payoff from Competition}}$$
$$\Rightarrow \Pi-(2\pi-f)\geq\sigma_p\delta V_E-(\sigma_{ip}-\sigma_i)\delta(V_I^i-V_I) \quad (4)$$

Note that the same static gains from cooperation (the LHS) occur for acquisition as they do for licensing. Where the two differ is in the dynamic implications. In particular, an acquisition causes the firms to jointly forgo a chance of earning V_E but also potentially improves their chances of earning V_I^i rather than V_I. Although this will only occur if $\sigma_{ip}>\sigma_i$. If, however, there are functional difficulties in integrating productive and innovative capabilities, this inequality might not hold; e.g., the innovative capabilities may be subsumed or extinguished in a larger organisation. In that case, acquisition reduces the likelihood of the incumbent becoming the lead innovator in the next generation.

As for the (conjectured) equilibrium payoffs in the acquisition case, we have:

$$V_I=\Pi+\delta V_I-\phi_E\left(\tau-\sigma_{ip}\delta(V_I^i-V_I)\right) \quad \text{(VI)''}$$

$$V_E=(1-\phi_E)\delta V_E+\phi_E\tau-c(\phi_E) \quad \text{(VE)''}$$

where, V_I^i is still determined according to (VI-i). The start-up's innovation prize is, therefore:

$$W_E = \tau - \delta V_E \qquad \text{(IB-E)''}$$

Using, the Nash bargaining solution, τ is given by: $\tau = \Pi\gamma + (2\pi - f)(1-\gamma) + \delta V_I - \sigma_p \gamma \delta V_E + \delta(\sigma_i(1-\gamma) + \sigma_{ip}\gamma)(V_I^i - V_I)$.

Given this, we can prove a similar proposition to part of Proposition 1 for the licensing case.

Proposition 2. *Acquisition is an equilibrium outcome for (i) δ sufficiently small and/or (ii) $\sigma_{ip} \geq \sigma_i$ and σ_p sufficiently small.*

Like Proposition 1, acquisition is an equilibrium when there is sufficient discounting of the future. However, there are also some differences. In particular, we cannot establish sufficient conditions for acquisition not to be an equilibrium even when $\delta \to 1$ and the capabilities are chosen to maximise the RHS of (4). In this situation, we cannot rule out that $\Pi - (2\pi - f) \geq V_E + V_I^i - V_I$.

Of course, in reality, firms may have options of choosing between licensing and acquisition as a mode of cooperative commercialisation. Comparing (1) and (4), acquisition will have higher gains from trade than licensing if:

$$\begin{aligned} &\sigma_p \delta V_E - (\sigma_{ip} - \sigma_i)\delta(V_I^i - V_I) \geq \left(\sigma_i - \sigma_p\right)\delta\left(V_I^i - V_E - V_I\right) \\ &\Rightarrow (\sigma_{ip} - \sigma_p)(V_I^i - V_I) \geq \sigma_i V_E \end{aligned} \qquad (5)$$

The interpretation here is quite intuitive. Acquisition yields the benefit of a potentially higher probability of incumbent innovation leadership with the cost of losing a chance at an entrant position in the next generation. That these are the drivers is confirmed by the following proposition:

Proposition 3. *Suppose that δ sufficiently small so that competition is not an equilibrium outcome. Acquisition is an equilibrium outcome as $\sigma_i \to 0$ and $\sigma_{ip} > \sigma_p$. Licensing is an equilibrium outcome if $\sigma_{ip} \leq \sigma_p$.*

The choice between acquisition and licensing would, in fact, hold for any δ. What this implies is that, from Proposition 1, we know that licensing is not an equilibrium outcome when, for example, $\sigma_p - \sigma_i \to 1$. In this situation, so long as $\sigma_{ip} < 1$, licensing would be chosen above acquisition and so, by implication, acquisition is not an equilibrium outcome. This is consistent with the intuition given by examining (4) alone.

It is worth emphasizing that Proposition 3 highlights a critical difference between standard economic considerations and a broader organizational or strategy viewpoint. In economics, the principle of 'selective intervention' would suggest that adding the innovative capabilities of the entrepreneur to an established firm would 'do no harm' to the established firms prospects in becoming an innovation leader in the future. That is, there would be a presumption that $\sigma_{ip} > \sigma_p$. Note that in this situation, acquisition would be preferred to licensing.

However, if, because of difficulties in contracting over the leverage of dynamic capabilities, it was the case that $\sigma_{ip} < \sigma_p$, the firms may choosing a licensing agreement allowing the entrepreneur to return as an independent innovator rather than bringing the entrepreneur inside the firm. This is, indeed, a common choice in cooperative commercialisation (Hellmann, 1996). The model here argues that this can only be rationalised if, not only does the entrepreneur add no value to an established firm but, in addition, causes that firm to be less likely to be a future innovator.

5. 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

As the focus here is on start-up innovation choices, I adopt a simplying assumption here that $\phi_I = 0$ and $\sigma_{ip} = 0$; that is, $V_I^i = V_I$. Here I will also 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 $\sigma_i = \sigma_p$ 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 ϕ_E .

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 $\Pi\gamma+(2\pi-f)(1-\gamma)$ whereas the returns from entry under no licensing are $\pi-f$. 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 and those under competition whereas under no licensing the innovator appropriates its individual competitive profits. As industry profits under monopoly exceed those following competition, the prize under licensing is higher.

Countering this are future benefits. When $\sigma_i=\sigma_p$, 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 δ, that advantage maybe greater under no licensing than it is under licensing. To see this, note that:

$$V_I-V_E=\frac{(1-\delta)((1-\phi_E)\Pi+\phi_E f)-\delta(1-\sigma_p)(\pi-f)\phi_E^2+(1-\delta-\delta\phi_E(1-\sigma_p))c(\phi_E)}{(1-\delta)^2+\delta\phi_E(2(1-\delta)+\delta(1-\sigma_p)\phi_E)} \quad \text{(IA-Comp)}$$

$$V_I-V_E=\frac{(1-\delta)\Pi-((1-\gamma)(\pi-f)+\gamma(\Pi-\pi))\phi_E(2(1-\delta)+\delta(1-\sigma_p)\phi_E)+(1-\delta-\delta\phi_E(1-\sigma_p))c(\phi_E)}{(1-\delta)^2+\delta\phi_E(2(1-\delta)+\delta(1-\sigma_p)\phi_E)} \quad \text{(IA-Coop)}$$

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

$$\gamma\delta(1-\sigma_p)\phi_E\geq(1-2\gamma)(1-\delta) \quad (6)$$

However, this will not hold for all parameter values but it will hold if $\gamma\geq\frac{1}{2}$. When entrant bargaining power is relatively high, under cooperation their profits are higher while the incumbent's is lower. This reduces 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. Looking at the overall prize, *W*, (IB-Coop) exceeds (IB-Comp) if:

$$(1-\delta)\frac{(\Pi-2\pi+f)\left(\gamma(1-\delta)+\delta\phi_E\right)}{(1-\delta)^2+\delta\phi_E(2(1-\delta)+\delta(1-\sigma_p)\phi_E)}\geq 0 \quad (7)$$

Not surprisingly, when there is complete discounting ($\delta = 0$), it is clear from (6) 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:[15]

Proposition 4. *When $\sigma_i = \sigma_p$, the equilibrium innovation rate is higher under licensing than no licensing.*

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 σ_p; 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 σ_p

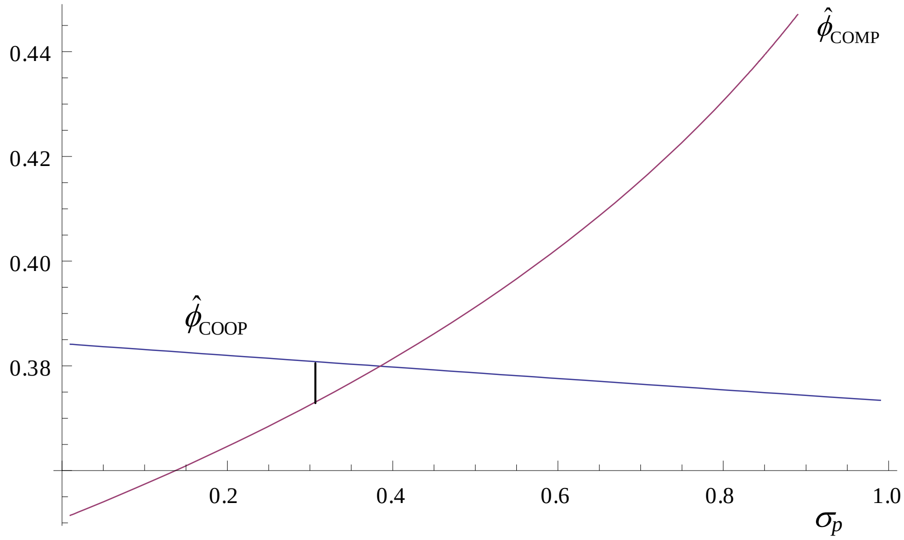
[15] The qualifier is made only for notational simplicity. Whenever, licensing is an equilibrium outcome this the proposition holds.

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 (σ_p) becomes stronger? As noted earlier, ceteris paribus, as σ_p rises the commercialisation regime can switch from licensing to competition. Over the range where licensing is an equilibrium, innovation rates will fall with σ_p 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 2 illustrates this for our numerical solution. In this example, the commercialisation regime moves from licensing to competition as $\sigma_p \gtrsim 0.3$. Notice that the innovation rate declines and then takes a discrete downward jump as we move from licensing to competition. The innovation rate then rises again and when $\sigma_p = 1$ (for this example) actually exceeds the rate when $\sigma_p = 0$.

Figure Two ($c(\phi)=\phi^2$, $\Pi=1$, $\pi=0.4$, $f=0.3$, $\gamma=0.5$, $\delta=0.9$, $\sigma_i=0$)



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, σ_i). 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 σ_i .

What this means is that as σ_i rises, the commercialisation regime may switch from competition to cooperation and the equilibrium rate switch from a constant level (unrelated to σ_i) 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.

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 feed back to determine the general relationship between commercialisation activities of start-ups and their share of innovation across industries.

In this regard, perhaps the most interesting finding was that start-ups and incumbents may not sign cooperative licensing agreements even though this would prevent the dissipation of monopoly profits and duplication of complementary investments. This occurred because to do so would send the start-up firm back to compete for the next generation of innovation in situations where the incumbent had stronger capabilities in this regard. This naturally leads to the question as to whether the firms could choose which one of them would return to innovative competition and which would remain as the incumbent.

This is an interesting issue and in many respects goes to the heart of what a dynamic capability is and how it is acquired. An incumbent is likely to be strong because of its previous product market position and this likely relates to investments it has made in the past. An entrant would have to similarly make those investments to strengthen its future role and thus, one of the gains from licensing (preventing such duplication) would be lost. In addition, with anti-trust laws, it is not clear that the incumbent could cede its product market position so readily. Non-exclusive licensing might play a role here but there would be some on-going dissipation of monopoly rents. Similarly, the start-up could acquire the incumbent. However, this might necessarily preclude it from becoming a strong innovative entrant unless some form of restructuring was possible. Thus, there appears to be good reasons why changing positions is not a simple choice and so it is natural to explore innovative dynamics when this is impossible. However, a proper exploration of these issues remains an open area for future research.

There are several other directions in which the results of this paper could be extended and explored in future research. First, 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 is 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:

Competition Case

Solving (VI), (VIi) and (VE) simultaneously yields.

$$V_E = -\frac{c(\phi_E)(-1+\delta+\delta(-1+\sigma_{ip})\phi_I)(1-\delta+\delta\phi_E)+\phi_E\left((-1+\delta)((-f+\pi)(-1+\delta)-\delta\Pi)+\delta\left(\begin{array}{c}((-1+\delta)(f-2\pi+\Pi)+(\pi(-1+\delta)+\Pi)\sigma_i)\phi_E+c(\phi_I)\sigma_i(-1+\delta-\delta\phi_E)\\ +\phi_I(\Delta\sigma_i(1-\delta+\delta\phi_E)+(-1+\sigma_{ip})((-f+\pi)(-1+\delta)-\delta\Pi+\delta(f-2\pi+\Pi)\phi_E))\end{array}\right)\right)}{-\delta(-1+\sigma_{ip})\phi_I\left(-(-1+\delta)^2+\delta\phi_E(2(-1+\delta)+\delta(-1+\sigma_p)\phi_E)\right)+(-1+\delta)\left((-1+\delta)^2+\delta\phi_E(2-2\delta+\delta(1+(-1+\sigma_i)\sigma_p)\phi_E)\right)}$$

$$V_I = -\frac{\begin{array}{c}(-1+\delta)^2\Pi+(-1+\delta)(\pi(-1+\delta)+\Pi-2\delta\Pi+\delta c(\phi_E)\sigma_p)\phi_E+\delta(-(-1+\delta)(\pi-\Pi)+((f-\pi)(-1+\delta)+\delta(\Pi-c(\phi_I))\sigma_i)\sigma_p)\phi_E^2\\ +\delta\phi_I((-1+\delta)\Pi(-1+\sigma_{ip})+(-1+\sigma_{ip})(\pi(-1+\delta)+\Pi-2\delta\Pi+\delta c(\phi_E)\sigma_p)\phi_E+\delta(\pi-\Pi+(-f+\pi+\Delta\sigma_i)\sigma_p+\sigma_{ip}(-\pi+\Pi+(f-\pi)\sigma_p))\phi_E^2)\end{array}}{-\delta(-1+\sigma_{ip})\phi_I\left(-(-1+\delta)^2+\delta\phi_E(2(-1+\delta)+\delta(-1+\sigma_p)\phi_E)\right)+(-1+\delta)\left((-1+\delta)^2+\delta\phi_E(2-2\delta+\delta(1+(-1+\sigma_i)\sigma_p)\phi_E)\right)}$$

$$V_I^i = \frac{\begin{array}{c}-\Pi((-1+\delta)^2+\delta\phi_E(2-2\delta+\delta(1+(-1+\sigma_i)\sigma_p)\phi_E))+c(\phi_I)((-1+\delta)^2+\delta\phi_e(2-2\delta+\delta(1+(-1+\sigma_i)\sigma_p)\phi_E))\\ -\phi_I\left(\begin{array}{c}(-1+\delta)((-1+\delta)\Delta-\delta\Pi)+\delta\phi_E(-(-1+\delta)(\pi+2\Delta)+(-1+2\delta)\Pi-\delta c(\phi_E)\sigma_p+\delta(\pi+\Delta-\Pi+(-f+\pi-\Delta+\Delta\sigma_i)\sigma_p)\phi_E)\\ +\delta\sigma_{ip}((-1+\delta)\Pi+\phi_E(\pi(-1+\delta)+\Pi-2\delta\Pi+\delta c(\phi_E)\sigma_p+\delta(-\pi+\Pi+(f-\pi)\sigma_p)\phi_E))\end{array}\right)\end{array}}{-\delta(-1+\sigma_{ip})\phi_I\left(-(-1+\delta)^2+\delta\phi_E(2(-1+\delta)+\delta(-1+\sigma_p)\phi_E)\right)+(-1+\delta)\left((-1+\delta)^2+\delta\phi_E(2-2\delta+\delta(1+(-1+\sigma_i)\sigma_p)\phi_E)\right)}$$

Cooperation Case (Licensing)

Solving (VI)’, (VIi) and (VE)’ simultaneously yields.

$$V_E = \frac{\begin{array}{c}c(\phi_E)(\delta(-1+\sigma_{ip})\phi_I(1-\delta+\delta\phi_E)+(-1+\delta)(1-\delta+\delta(1+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_p)\phi_E))\\ +\phi_E\left(\begin{array}{c}(-(\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)-(\gamma(-1+\delta)-\delta)\Pi)(1-\delta+\delta\sigma_p\phi_E)-\delta c(\phi_I)((-1+\gamma)(-1+\delta)\sigma_i+\sigma_p(\gamma-\gamma\delta+\delta\phi_E))\\ +\delta\phi_I(\pi(-1+2\gamma)(-1+\delta)+f(-1+\gamma+\delta-\gamma\delta)+(\gamma+\delta-\gamma\delta)\Pi+(-1+\gamma)(-1+\delta)\Delta\sigma_i+((\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)+(\gamma(-1+\delta)-\delta)\Pi)\sigma_{ip}+\Delta\sigma_p(\gamma-\gamma\delta\end{array}\right.\end{array}}{-(-1+\delta)^3+\delta\left((-1+\delta)\phi_E\left((1-\delta)(-2+\sigma_i-\sigma_p)+\delta\left((-1+\sigma_i)(1+(-1+\gamma)\sigma_i)+(-1+\gamma)\sigma_p-\gamma\sigma_p^2\right)\phi_E\right)+(-1+\sigma_{ip})\phi_I\left(-(-1+\delta)^2+\delta\phi_E((1-\delta)(-2+\gamma\sigma_i-\gamma\sigma_p)+\delta(-1+\sigma_i)\phi_E)\right)\right)}$$

$$V_I = \frac{\begin{array}{c}(-1+\delta)^2\Pi-(-1+\delta)((\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)+(\gamma(-1+\delta)+\delta)\Pi-\delta(\Pi+(-1+\gamma)c(\phi_I)-(-1+\gamma)c(\phi_E))\sigma_i+\delta(\Pi+(-1+\gamma)c(\phi_I)-\gamma c(\phi_E))\sigma_p)\phi\\ +\delta\left(\begin{array}{c}(1-\sigma_i)((-1+\delta)(\pi+f(-1+\gamma)-2\pi\gamma+\gamma\Pi)+(-1+\gamma)\delta(\Pi-c(\phi_I))\sigma_i)-(-1+\gamma)\delta(\Pi-c[\phi_i])\sigma_p\\ +\gamma\delta(\Pi-c(\phi_I))\sigma_p^2\end{array}\right)\phi_E^2\\ +\delta\phi_I\left(\begin{array}{c}\Pi-\delta\Pi+((\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)+(\gamma(-1+\delta)+\delta)\Pi-((-1+\gamma)(-1+\delta)\Delta+\gamma\delta\Pi-(-1+\gamma)\delta c(\phi_E))\sigma_i+((-1+\gamma)(-1+\delta)\Delta+\gamma\delta\Pi-\gamma\delta c(\phi_E))\sigma\\ +\delta((-1+\sigma_i)(\pi+f(-1+\gamma)-2\pi\gamma+\gamma\Pi-(-1+\gamma)\Delta\sigma_i)-(-1+\gamma)\Delta\sigma_p+\gamma\Delta\sigma_p^2)\phi_E^2+\sigma_{ip}\left(\begin{array}{c}(-1+\delta)\Pi+\left(\begin{array}{c}(f-f\gamma+\pi(-1+2\gamma))(-1+\delta)-(\gamma(-1+\delta)+\delta)\Pi\\ +\delta(\gamma\Pi-(-1+\gamma)c(\phi_E))\sigma_i+\gamma\delta(-\Pi+c(\phi_E))\sigma_p\end{array}\right.\\ -\delta(\pi+f(-1+\gamma)-2\pi\gamma+\gamma\Pi)(-1+\sigma_i)\phi_E^2\end{array}\right.\end{array}\right.\end{array}}{-(-1+\delta)^3+\delta\left((-1+\delta)\phi_E\left((1-\delta)(-2+\sigma_i-\sigma_p)+\delta\left((-1+\sigma_i)(1+(-1+\gamma)\sigma_i)+(-1+\gamma)\sigma_p-\gamma\sigma_p^2\right)\phi_E\right)+(-1+\sigma_{ip})\phi_I\left(-(-1+\delta)^2+\delta\phi_E((1-\delta)(-2+\gamma\sigma_i-\gamma\sigma_p)+\delta(-1+\sigma_i)\phi_E)\right)\right)}$$

$$V_I^i = \frac{\begin{array}{c}\Pi((-1+\delta)^2+\delta\phi_E((-1+\delta)(-2+\sigma_i-\sigma_p)+\delta(1+(-2+\gamma)\sigma_i-(-1+\gamma)\sigma_i^2+\sigma_p+\gamma(-1+\sigma_p)\sigma_p)\phi_E))\\ +c[\phi_I](-(-1+\delta)^2+\delta\phi_E((1-\delta)(-2+\sigma_i-\sigma_p)+\delta((-1+\sigma_i)(1+(-1+\gamma)\sigma_i)+(-1+\gamma)\sigma_p-\gamma\sigma_p^2)\phi_E))\\ +\phi_I\left(\begin{array}{c}(-1+\delta)((-1+\delta)\Delta-\delta\Pi)+\delta\left(\begin{array}{c}(-1+\delta)(\pi+f(-1+\gamma)-2\pi\gamma-2\Delta)+(\gamma(-1+\delta)+\delta)\Pi+((-1+\delta)\Delta-\gamma\delta\Pi+(-1+\gamma)\delta c(\phi_E))\sigma_i\\ +(\Delta-\delta\Delta+\gamma\delta\Pi-\gamma\delta c(\phi_E))\sigma_p\end{array}\right)\phi_e\\ +\delta^2\left(\begin{array}{c}(-1+\sigma_i)(\pi+f(-1+\gamma)-2\pi\gamma-\Delta+\gamma\Pi-(-1+\gamma)\Delta\sigma_i)\\ -(-1+\gamma)\Delta\sigma_p+\gamma\Delta\sigma_p^2\end{array}\right)\phi_E^2+\delta\sigma_{ip}\left(\begin{array}{c}(-1+\delta)\Pi+\left(\begin{array}{c}(f-f\gamma+\pi(-1+2\gamma))(-1+\delta)\\ -(\gamma(-1+\delta)+\delta)\Pi+\delta(\gamma\Pi-(-1+\gamma)c(\phi_E))\sigma_i+\gamma\delta(-\Pi+c(\phi_E))\end{array}\right.\\ -\delta(\pi+f(-1+\gamma)-2\pi\gamma+\gamma\Pi)(-1+\sigma_i)\phi_E^2\end{array}\right.\end{array}\right.\end{array}}{-(-1+\delta)^3+\delta\left((-1+\delta)\phi_E\left((1-\delta)(-2+\sigma_i-\sigma_p)+\delta\left((-1+\sigma_i)(1+(-1+\gamma)\sigma_i)+(-1+\gamma)\sigma_p-\gamma\sigma_p^2\right)\phi_E\right)+(-1+\sigma_{ip})\phi_I\left(-(-1+\delta)^2+\delta\phi_E((1-\delta)(-2+\gamma\sigma_i-\gamma\sigma_p)+\delta(-1+\sigma_i)\phi_E)\right)\right)}$$

Cooperation Case (Acquisition)

Solving (VI)”, (VIi) and (VE)” simultaneously yields.

$$V_E = \frac{\begin{matrix} -c(\phi_E)(\delta(-1+\sigma_{ip})\phi_I(1-\delta+\delta\phi_E)+(-1+\delta)(1-\delta+\delta(1+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_{ip})\phi_E)) \\ -\phi_E\left(\begin{matrix} (-(\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)-(\gamma(-1+\delta)-\delta)\Pi)(1-\delta+\delta\sigma_{ip}\phi_E)-\delta c(\phi_I)((-1+\gamma)(-1+\delta)\sigma_i+\sigma_{ip}(\gamma-\gamma\delta+\delta\phi_E)) \\ +\delta\phi_I(\pi(-1+2\gamma)(-1+\delta)+f(-1+\gamma+\delta-\gamma\delta)+(\gamma+\delta-\gamma\delta)\Pi+(-1+\gamma)(-1+\delta)\Delta\sigma_i+\sigma_{ip}((-1+\delta)(\pi+f(-1+\gamma)-\gamma(2\pi+\Delta))\ +(\gamma(-1+\delta)-\delta)\Pi+\delta\Delta\phi_E)) \end{matrix}\right. \end{matrix}}{(-1+\delta)^3+\delta\left((-1+\delta)\phi_E((1-\delta)(2+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_{ip}+\gamma\sigma_p)+\delta(1+(-1+\gamma)\sigma_i+\sigma_{ip}+\gamma\sigma_{ip}(-1+\sigma_p))\phi_E)+(-1+\sigma_{ip})\phi_I\left((-1+\delta)^2+\delta\phi_E((1-\delta)(2+\gamma\sigma_p)+\delta\phi_E)\right)\right)}$$

$$V_I = \frac{\begin{matrix} -(-1+\delta)^2\Pi+(-1+\delta)((\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)+(\gamma(-1+\delta)+\delta)\Pi+(-1+\gamma)\delta(\Pi-c[\phi_I])(\sigma_i-\sigma_{ip})+\gamma\delta(\Pi-c(\phi_E))\sigma_p)\phi_E \\ +\delta((1-\delta)(\pi+f(-1+\gamma)-2\pi\gamma+\gamma\Pi)-\delta(\Pi-c(\phi_I))((-1+\gamma)\sigma_i+\sigma_{ip}+\gamma\sigma_{ip}(-1+\sigma_p)))\phi_E^2 \\ -\delta\phi_I\left(\begin{matrix} \Pi-\delta\Pi+\phi_E((\pi+f(-1+\gamma)-2\pi\gamma)(-1+\delta)+(\gamma(-1+\delta)+\delta)\Pi+\gamma\delta(\Pi-c(\phi_E))\sigma_p-\delta(\pi+f(-1+\gamma)-2\pi\gamma+\gamma\Pi)\phi_E+(-1+\gamma)\Delta\sigma_i(1-\delta+\delta\phi_E)) \\ +\sigma_{ip}((-1+\delta)\Pi+\phi_E((1-\delta)(\pi+f(-1+\gamma)+\Delta-\gamma(2\pi+\Delta))\ -(\gamma(-1+\delta)+\delta)\Pi+\delta(\pi+f(-1+\gamma)+\Delta+\gamma(-2\pi-\Delta+\Pi))\phi_E+\gamma\delta\sigma_p(-\Pi+c(\phi_E)+\Delta\phi_E))) \end{matrix}\right) \end{matrix}}{(-1+\delta)^3+\delta\left((-1+\delta)\phi_E((1-\delta)(2+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_{ip}+\gamma\sigma_p)+\delta(1+(-1+\gamma)\sigma_i+\sigma_{ip}+\gamma\sigma_{ip}(-1+\sigma_p))\phi_E)+(-1+\sigma_{ip})\phi_I\left((-1+\delta)^2+\delta\phi_E((1-\delta)(2+\gamma\sigma_p)+\delta\phi_E)\right)\right)}$$

$$V_I^i = \frac{\begin{matrix} -\Pi\left((-1+\delta)^2+\delta\phi_E\left(\begin{matrix}(1-\delta)(2+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_{ip}+\gamma\sigma_p) \\ +\delta(1+(-1+\gamma)\sigma_i+\sigma_{ip}+\gamma\sigma_{ip}(-1+\sigma_p))\phi_E\end{matrix}\right)\right)+c(\phi_I)\left((-1+\delta)^2+\delta\phi_E\left(\begin{matrix}(1-\delta)(2+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_{ip}+\gamma\sigma_p) \\ +\delta(1+(-1+\gamma)\sigma_i+\sigma_{ip}+\gamma\sigma_{ip}(-1+\sigma_p))\phi_E\end{matrix}\right)\right) \\ -\phi_I\left(\begin{matrix} (-1+\delta)((-1+\delta)\Delta-\delta\Pi)+\delta\phi_E\left(\begin{matrix}(-1+\delta)(\pi+f(-1+\gamma)-2\pi\gamma-2\Delta) \\ +(\gamma(-1+\delta)+\delta)\Pi+\gamma(\Delta-\delta\Delta+\delta\Pi-\delta c(\phi_E))\sigma_p+\delta(f-f\gamma+\pi(-1+2\gamma)+\Delta-\gamma\Pi)\phi_E+(-1+\gamma)\Delta\sigma_i(1-\delta+\delta\phi_E)\end{matrix}\right) \\ +\delta\sigma_{ip}((-1+\delta)\Pi+\phi_E((1-\delta)(\pi+f(-1+\gamma)+\Delta-\gamma(2\pi+\Delta))\ -(\gamma(-1+\delta)+\delta)\Pi+\delta(\pi+f(-1+\gamma)+\Delta+\gamma(-2\pi-\Delta+\Pi))\phi_E+\gamma\delta\sigma_p(-\Pi+c(\phi_E)+\Delta\phi_E))) \end{matrix}\right) \end{matrix}}{(-1+\delta)^3+\delta\left((-1+\delta)\phi_E((1-\delta)(2+(-1+\gamma)\sigma_i-(-1+\gamma)\sigma_{ip}+\gamma\sigma_p)+\delta(1+(-1+\gamma)\sigma_i+\sigma_{ip}+\gamma\sigma_{ip}(-1+\sigma_p))\phi_E)+(-1+\sigma_{ip})\phi_I\left((-1+\delta)^2+\delta\phi_E((1-\delta)(2+\gamma\sigma_p)+\delta\phi_E)\right)\right)}$$

Proof of Proposition 1

Using the values computed above, substituting them into (1), and taking the limit as δ approaches 0, we get $\Pi - 2\pi + f > 0$. Also, looking at (1), if $\sigma_i = \sigma_p$, the same value arises. So licensing is an equilibrium in either case.

For the possibility that licensing is not an equilibrium, note that when $\sigma_p = 1$ and $\sigma_i = 0$, taking the limit as δ approaches 1, the gains from trade become:

$$\Pi - (2\pi - f) - \frac{\Pi - c(\hat{\phi}_E)}{\hat{\phi}_E} \tag{8}$$

We wish to show that this is negative. Suppose, not. Re-arranging we have: $(-2\pi + f)\hat{\phi}_E \geq \Pi(1-\hat{\phi}_E) - c(\hat{\phi}_E)$. Note that, as $\delta \to 1$, $W_E \to c(\phi_E)/\phi_E$. At $\hat{\phi}_E$, this implies that $c(\hat{\phi}_E) \to c'(\hat{\phi}_E)/\hat{\phi}_E$, which, as $c(.)$ is non-decreasing with $c(0) = 0$, can only be true if $\hat{\phi}_E \to 0$ (as this is the point where average equals marginal cost). Thus, in equilibrium, (8) cannot be positive and so licensing is not an equilibrium outcome in this case.

Now consider what happens when $\sigma_p = 0$ and $\sigma_i = 1$. Taking the limit as δ approaches 1, the gains from trade become:

$$\Pi - (2\pi - f) - \frac{\left(\Pi - c(\hat{\phi}_E)\right)(1-\sigma_{ip})\phi_I\hat{\phi}_E}{0} \tag{9}$$

which is clearly negative.

Proof of Proposition 3

Using the (conjectured) equilibrium payoffs for either licensing or acquisition, as δ goes to 0, (5) becomes:

$$(\sigma_{ip}-\sigma_p)\left(\phi_E(\gamma(\Pi-2\pi+f)+\pi-f)+\phi_I\Delta-c(\phi_I)\right)\geq\sigma_i\left(\phi_E(\gamma(\Pi-2\pi+f)+\pi-f)-c(\phi_E)\right)$$

Acquisition will be the equilibrium if this is positive otherwise licensing is the equilibrium. Putting in the parameter values in the proposition confirms this.

References

Adner, R. and P. Zemsky (2005), "Disruptive Technologies and the Emergence of Competition," *RAND Journal of Economics*, 36 (2), pp.361-377.

Anton, J.J. and D.A. Yao (1994), "Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights," *American Economic Review*, 84 (1), pp.190-209.

Arora, A. (1995), "Licensing Tacit Knowledge: Intellectual Property Rights and the Market for Know-How," *Economics of Innovation & New Technology*, Vol. 4, pp.41-59.

Arora, A. and M. Ceccagnoli (2005), "Patent Protection, Complementary Assets and Firms: Incentives for Technology Licensing," *Management Science*, forthcoming.

Arrow, K.J. (1962), "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity*, Princeton University Press: Princeton, pp.609-625.

Bartlett, C.A. (1983), "EMI and the CT Scanner (A)," *Harvard Business School Case*, 383-194.

Cape, E.G. (1999), "Disruptive Technology a Heartbeat Away: Ecton, Inc.," *Harvard Business School Case*, 9-699-018.

Gabler, N. (2006), *Walt Disney: The Triumph of the American Imagination*, Knopf: New York.

Gans, J.S., D. Hsu and S. Stern (2002), "When Does Start-Up Innovation Spur the Gale of Creative Destruction?" *RAND Journal of Economics*, 33 (4), pp.571-586.

Gans, J.S. and S. Stern (2000), "Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction," *Journal of Economics and Management Strategy*, 9 (4), pp.485-511.

Gans, J.S. and S. Stern (2003), "The Product Market and the 'Market for Ideas': Commercialization Strategies for Technology Entrepreneurs," *Research Policy*, 32 (2), pp.333-350.

Gilbert, R. and D. Newbery (1982), "Preemptive Patenting and the Persistence of Monopoly," *American Economic Review*, 72 (3), pp.514-526.

Green, R. and S. Scotchmer (1995), "On the Division of Profit between Sequential Innovators," *RAND Journal of Economics* 26, pp. 20-33.

Hellmann, T. (1996), "Symantec Corporation: Acquiring Entrepreneurial Companies," *Stanford Graduate School of Business Case*, S-SM-27.

Hsu, D. (2006), "Venture Capitalists and Cooperative Start-Up Commercialization Strategy," *Management Science*, 52, pp.204-219.

Katz, M.L. and C. Shapiro (1987), "R&D Rivalry with Licensing or Imitation," *American Economic Review*, 77 (3), pp.402-420.

O'Donoghue,T., S. Scotchmer and J. Thisse (1998), "Patent Breadth, Patent Life and the Pace of Technological Improvement," *Journal of Economics and Management Strategy,* 7 (1), pp.1-32.

Pisano, G. (1994), "Nucleon, Inc.," *Harvard Business School Case*, 9-692-041.

Reinganum, J.F. (1989), "On the Timing of Innovation," in R. Schmalansee and R. Willig (eds.), *Handbook of Industrial Organization*, Vol.1, Elsevier, pp. 849-908.

Salant, S.W. (1984), "Preemptive Patenting and the Persistence of Monopoly: Comment," *American Economic Review*, 74 (1), pp.247-250.

Scotchmer, S. (2005), *Innovation and Incentives*, MIT Press: Cambridge (MA).

Segal, I. and M. Whinston (2005), "Antitrust in Innovative Industries," *American Economic Review*, forthcoming.

Sutton, J. (2002), "Rich Trades, Scarce Capabilities: Industrial Development Revisited," *The Economic and Social Review*, 33 (1), pp.1-22.

Teece, D.J. (1987), "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy," in D.J. Teece (ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*, Ballinger: Cambridge (MA), pp.185-220.

Teece, D.J., G. Pisano and A. Shuen (1997), "Dynamic Capabilities and Strategic Management," *Strategic Management Journal*, 18 (7), pp.509-533.