Profiting from Technological Capabilities: Technology Commercialization Strategy in a Dynamic Context

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This paper analyzes the technology commercialization strategy of an innovating firm when the incumbent firms possess specialized commercialization capabilities. According to the predominant framework, if the innovation is protected by a tight appropriability regime the optimal strategy is to license the innovation to an incumbent product firm. This paper argues by contrast that if the innovating firm has the ability to learn from its experience in the commercialization process and is likely innovate in the same product field in future, its optimal strategy may – under certain conditions – be to commercialize alone or to pursue co-promotion, a hybrid arrangement whereby it licenses the innovation but retains the rights to participate in the commercialization process. Using a game-theoretic model of the technology commercialization process, the paper derives the conditions in which licensing, self-commercialization, and co-promotion are equilibrium outcomes. It then uses these to explain the pattern of technology commercialization arrangements pursued by biotech firms attempting to commercialize 1590 identifiable products in the pharmaceutical industry between 1978 and 2008. The results show that a firm is significantly more likely to use the hybrid strategy when there are more firms competing to license the innovation, when there is a higher probability of commercializing a subsequent product in the same product field in future, and when it is in a stronger financial position.
1. Introduction

A critical decision facing a technology-based firm that has generated an innovation is how to access the complementary assets necessary to bring a product to market. According to the predominant framework, developed by Teece (1986), if the innovation is protected by a tight appropriability regime but the innovating firm is in a disadvantaged position relative to the incumbent product firms with respect to those assets, an innovating firm’s optimal strategy is to license the commercialize rights to an incumbent product. The alternative – integrating downstream into the complementary activities – is not only more risky but may also delay commercialization, reducing the rents it can capture from the innovation. Nevertheless, in exchange for access to the product firm’s complementary assets, the technology firm must share the returns from its innovation, and it remains in a disadvantaged position for commercializing subsequent innovations. If it does this for successive innovations it is unlikely to earn superior profits over the long term.1

In this paper I show that, when the technology firm has specialized technological capabilities, so that it expects to innovate repeatedly in a particular field, and it has the ability to learn from its experience in the commercialization process, it may be better off commercializing alone. Moreover, under certain conditions its optimal strategy may be to pursue a hybrid between these two: contracting for access to the complementary assets but retaining rights to participate in the commercialization process.

To understand what drives the technology firm’s choice between these alternative commercialization strategies, I develop a dynamic game-theoretic model of a technology firm choosing its strategy in the situation where it has the opportunity to learn from its experience in the commercialization process and acquire capabilities from which it may benefit in subsequent commercialization attempts. I use the model to derive the conditions under which the both the technology firm and an established firm are willing to agree to a co-promotion arrangement vis-à-vis the traditional or “pure” licensing arrangement, or when the firms do not reach an agreement and the biotech firm attempts to commercialize the innovation alone.

I use the conditions derived from the model to explain the pattern of technology commercialization arrangements pursued by biotech firms attempting to bring innovations to the pharmaceutical product market. Since the inception of the industry in 1978, licensing has been the predominant mode by

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1 By superior profits I mean earnings above the costs of factor inputs that reward innovators for engaging in the uncertain process of innovation, or what are sometimes referred to as Schumpeterian rents.
which innovations are commercialized in the biotech industry. However, the biotech firm often seeks to advance the innovation as far as possible through the commercialization process before licensing it. Moreover, in recent years, biotech firms increasingly have sought to retain rights to participate in the marketing and sales process in alliances with pharmaceutical firms (an arrangement known as “co-promotion”). I report evidence from interviews with biotech executives that suggest this arrangement is part of a strategy by which the biotech firms learn about the commercialization process and thereby acquire the capabilities necessary to commercialize future innovations alone. I then analyze the technology commercialization arrangements used in a dataset of 1590 instances in which a biotech firm held U.S. marketing rights to an identifiable biopharmaceutical product that was in clinical trials between 1978 and 2008. The results show that a biotech firm is significantly more likely to enter a co-promotion arrangement when there is a higher probability of commercializing a subsequent product in the same product field in future, when there are more firms competing to license the innovation, and when it is in a stronger financial position.

The next section explains the relationship between this paper and the prior literature on technology commercialization strategy and alliance structure. Section 3 presents the model of the technology-based firm choosing its commercialization strategy and derives the conditions under which two firms are likely to agree to co-promotion. Section 4 describes the empirical analysis of the pattern of technology commercialization arrangements in the biopharmaceutical industry. I conclude in section 5 with implications for managers.

### 2. Related literature

The paper builds on the framework proposed by Teece in his seminal paper on “Profiting from Technological Innovation” (Teece, 1986). Teece framed the innovating firm’s strategic decision as a choice between contracting with an established firm and integrating into the complementary assets to do the commercialization alone, and emphasized the role of the appropriability regime surrounding the innovation and the innovating firm’s position relative to the complementary assets. He argued that if the innovating firm has tight appropriability over its innovation but the established product firms are better positioned with respect to the complementary assets then the innovating firm’s optimal strategy is to contract with an established firm to commercialize the innovation. However, since the innovating firm innovates only once, Teece did not consider how the firm’s choice of commercialization mode might affect its options for commercializing future innovations. Moreover, although he acknowledges that the innovating firm that contracts for access will have to share profits with the holders of the complementary assets, Teece did not explain how a technology-based firm can overcome its disadvantaged position and thereby earn superior profits over the long term. Furthermore, although Teece mentions that firms may use “mixed modes” in transitional phases (Teece, 1986, p.298), he did
not explicitly consider how a firm may use a hybrid arrangement to establish a position of sustainable competitive advantage.

Most subsequent research that explicitly builds on the Teece framework (Gans, Hsu, & Stern, 2002; Gans & Stern, 2003; Arora & Merges, 2004) has concentrated primarily on how the firm’s appropriability regime impacts its commercialization strategy. One exception is Jacobides, Knudsen, & Augier (2006), which – like this paper – focuses specifically on how a firm may strengthen its position relative to the requisite complementary assets. That paper argues that a technology firm is unable to affect its position directly through a bilateral relationship with the holders of those assets, but may instead be able to use mechanisms such as standards-setting bodies to influence the industry architecture and thereby strengthen its position relative to the complementary assets. By contrast, this paper demonstrates how a technology firm can strengthen its position directly by the way it structures the bilateral relationship.

This paper also contributes to the literature on the structure of alliance contracts. Most of the existing literature which has examined the structure of these arrangements in any detail has analyzed how they balance mitigating contractual hazards (governance) with providing the right incentives for investment (Pisano, 1989; Williamson, 1991; Oxley, 1997). A parallel literature, building on the ‘property rights’ framework (Grossman & Hart, 1986; Hart & Moore, 1990), has studied the extent to which contracts are designed to give the parties the optimal incentives for effort (e.g., Elfenbein & Lerner, 2003) and how their ability to do so is limited by the firms’ financial position and/or relative bargaining power (e.g., Aghion & Tirole, 1994; Lerner & Merges, 1998; Higgins, 2007). Although interview research (discussed below) suggests that achieving governance and providing incentives are relevant considerations in this context, it reveals that the technology firm’s primary motivation for retaining rights to participate in the commercialization process is acquiring the knowledge necessary to commercialize future products alone.

There is a large literature on learning through alliances (see, for instance, Hamel, 1991; Khanna, Gulati, & Nohria, 1998; Oxley & Sampson, 2004), a subset of which focuses on how the structure of the alliance may affect learning (Kogut, 1988; Mowery, Oxley, & Silverman, 1996).² However, this literature is primarily focused on horizontal, ‘knowledge sharing’ alliances (Grant & Baden-Fuller, 2005).

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² Kogut (1988) argues that joint ventures may be more effective for achieving knowledge transfer while Mowery at al (1996) show empirically that firms are more likely to achieve technological transfer through bilateral (vs unilateral) contracts.
2004) between firms with complementary technological portfolios (e.g., international technology alliances), in which learning from the other firm is the primary objective. By contrast, this paper focuses on the structure of vertical arrangements may affect learning, even when the primary objective is ‘accessing’ knowledge.

3. Theory and Hypothesis Development

In order to analyze the technology firm's commercialization strategy in a context where it generates successive innovations, we develop a dynamic game-theoretic model of the technology commercialization process.

The value of explicitly modeling the technology commercialization process is that it explicitly incorporates two important features of the environment that are difficult to analyze intuitively: (1) the strategic interaction between the technology and product firms in negotiating a commercialization agreement; and (2) the dynamic nature of the environment, in which the technology firm has the opportunity to learn from its prior experience and apply that knowledge in commercializing subsequent innovations. Incorporating these two features makes it possible to be more precise about the specific conditions under which the technology firm will pursue the alternative commercialization strategies and thereby to generate insights that are not intuitively obvious.

The set-up of the model is based on Gans (2007), which in turn builds on a framework developed by Segal & Whinston (2007). However, while Gans examined how the technology firm's choice of commercialization mode affects its ability to innovate in future periods and Segal & Whinston studied how market concentration affected the incentive to innovate, the model here is designed to analyze how the firm's choice of commercialization mode affects the firm's ability to capture value from future innovations. The structure of the technology commercialization game has been changed to more closely resemble the situation that exists in biotechnology industry and similar environments.

3.1 Model Setup

We suppose that there is a single technology firm \( T \) and \( N \) identical product firms \( P_1, \ldots, P_N \). \( T \) has generic technological capabilities, which enable it to generate innovations relating to a broad range of product fields, while each of the product firms \( P_i \) has technological capabilities that are specialized to the particular product field. At the same time, each of the product firms \( P_i \) has capabilities in commercialization (i.e., development and marketing) that are specialized to the particular product field while (at least initially) \( T \) has no special commercialization capabilities.
All firms engage in innovation each period. However, while each of the product firms $P_i$ generates innovation in the particular field with certainty, $T$ only generates an innovation in the particular product field with probability $\phi \in (0,1]$.

If $T$ generates an innovation in the particular product field, it negotiates with each of the product firms about entering into a technology commercialization arrangement, either (1) a pure licensing arrangement ($L$) or (2) a co-promotion arrangement ($CP$). However, if it does not come to an agreement then it commercializes alone ($NL$). $T$ negotiates with all product firms simultaneously and since they are identical there is equal probability of it entering into an agreement with any particular firm and from its perspective the identity of its partner is irrelevant.

Under a pure licensing arrangement ($L$), $P_i$ pays $T$ a fixed payment $X^L$, whether or not the commercialization is successful. In exchange $T$ grants $P_i$ the exclusive rights to attempt commercialization of the innovation and to capture any profits that result. Similarly, under a co-promotion arrangement ($CP$), $P_i$ pays $T$ a fixed payment $X^{CP}$ in exchange for $T$ granting $P_i$ the rights to attempt to commercialize the innovation and capture any profits. However, $T$ also retains the right to participate in the commercialization process alongside $P_i$, which means it is able to learn from observing $P_i$’s commercialization attempt. Finally if $T$ does not license the innovation then it retains the rights to commercialize the innovation alone. If $T$ enters into a technology commercialization arrangement, either licensing or co-promotion, it incurs transaction costs $c_i$ (which reflect the costs of executing, monitoring, and enforcing the agreement).

Once all negotiations have been concluded, the firms attempt to commercialize the innovations in their portfolios. We let $\sigma^S_i$ be the probability of successfully commercializing $T$’s innovation and $\sigma^S_{P_i}$ be the probability of successfully commercializing $P_i$’s innovation under different strategies, where $S \in \{L, CP, NL\}$ represents the commercialization strategy followed by $T$.

Once the commercialization attempts have been made, the firms that have successfully commercialized their products compete for the market. We assume that only product can be on the market in each period and that each commercialized product has an equal probability of being the winner. The firm whose product captures the market earns $\pi$ (for one period only) and the other firms earn nothing. However, if no firm commercializes an innovation successfully then all firms earn nothing in that period.
Let $\lambda^S_i$ be the probability that the innovation generated by firm $i \in \{T, P_i\}$ captures the market if $T$ pursues the commercialization strategy $S \in \{L, CP, NL\}$. The values of $\lambda^S_i$ are given by:

$$\lambda^S_i(\sigma^S_T, \sigma^S_{P_i}, N) = \sigma^S_T \sum_{k=1}^{N} \frac{1}{k+1} \left( \frac{N}{k} \right) \left( 1 - \sigma^S_{P_i} \right)^{N-k} \left( \sigma^S_{P_i} \right)^k$$

(1)

$$\lambda^S_{P_i}(\sigma^S_T, \sigma^S_{P_i}, N) = \sigma^S_{P_i} \sum_{k=0}^{N-1} \frac{1}{k+2} \left( \frac{N-1}{k+1} \right) \left( 1 - \sigma^S_{P_i} \right)^{N-k} \left( \sigma^S_{P_i} \right)^k$$

(2)

The subgame for any given period proceeds as follows:

1. All firms engage in innovation.

2. If $T$ has generated an innovation in the product field, it negotiates with each of the product firms about entering into a technology commercialization arrangement. The negotiation results in one of three outcomes: (1) $T$ enters a pure licensing arrangement ($L$) with a particular product firm ($P_i$), rejecting offers from all other product firms ($P_{-i}$); (2) $T$ enters a co-promotion arrangement ($CP$) with $P_i$, rejecting offers from all other product firms ($P_{-i}$); or (3) $T$ attempts to commercialize the innovation alone ($NL$).

3. The firms attempt to commercialize the products in their portfolios.

4. The firms that have successfully commercialized their products compete for the market.

5. Payoffs are realized.

At the end of each period, the subgame repeats. The only parameter in the model that changes from period to period is the value of $\sigma^NL_T$, which rises to be equal to $\sigma^NL_{P_i}$ if $T$ has acquired specialized commercialization capabilities. Hence there are only two states of the game: when $T$ has specialized commercialization capabilities and when it does not. To distinguish between the probabilities and payoffs under these two states of the game, we denote those after $T$ has acquired specialized commercialization capabilities by a hyphen (e.g., $NL$ becomes $NL'$). Since the parameters are constant across periods within the same state, the optimal strategies are also constant across periods within the same state.
Since the values of $\sigma_T^S$ and $\sigma_{\phi_T}^S$ are constant within a particular strategy and state, we use $\lambda_T^S(N)$ and $\lambda_{\phi_T}^S(N)$ to represent the values of $\lambda_T^S(\sigma_T^S, \sigma_{\phi_T}^S, N)$ and $\lambda_{\phi_T}^S(\sigma_T^S, \sigma_{\phi_T}^S, N)$ respectively. Since $\lambda_T(\sigma, \sigma, N) = \lambda_{\phi_T}(\sigma, \sigma, N)$, we further simplify notation by defining $\lambda_{\phi_T}(N)$ such that

$$\lambda_{\phi_T}(N) = \lambda_{\phi_T}^L(N) = \lambda_{\phi_T}^N(N) = \lambda_{\phi_T}^{NL}(N)$$

(3)

Additionally, we define $\lambda_T^0$ and $\lambda_{\phi_T}^0$ to represent the case when $T$ does not innovate in the field in a particular period - in which case, $\sigma_T = 0$. These variables correspond to

$$\lambda_T^0(N) = \lambda_T(0, \sigma, N)$$

(4)

$$\lambda_{\phi_T}^0(N) = \lambda_{\phi_T}(0, \sigma, N)$$

(5)

We refer to the process by which $T$ acquires the commercialization capabilities equivalent to a product firm as "experiential learning".

3.2 Workings of the model with $N = 1$ and $\phi = 1$

To begin with, we assume that $N = 1$, meaning only one product firm $P_1$ in a position to commercialize $T$'s innovation, and $\phi = 1$, so that $T$ always generates an innovation in the particular product field.

3.2.1 Benchmark without Experiential Learning

We first determine as a benchmark the case without experiential learning. Let $\Pi_T^L$ and $\Pi_T^{NL}$ denote $T$'s present discounted profits under licensing and not licensing (respectively) and let $\delta$ be a discount factor such that money in period $t+1$ is worth $\delta$ of the value in period $t$. The values of $\Pi_T^L$ and $\Pi_T^{NL}$ are given by the following expressions:

$$\Pi_T^L = X^L - c_t + \delta \Pi_T^L$$

$$\Pi_T^{NL} = \lambda_T^{NL}(1)\pi + \delta \Pi_T^{NL}$$
Let $\Pi^L_{P_i}$ be $P_i$'s present value of the expected profits when $T$ licenses and let $\Pi^{NL}_{P_i}$ be $P_i$'s present value of the expected profits when $T$ does not license. The values of $\Pi^L_{P_i}$ and $\Pi^{NL}_{P_i}$ are given by:

$$\Pi^L_{P_i} = \lambda^L_i(1)\pi - X^L + \lambda^L_i(1)\pi + \delta\Pi^L_{P_i}$$

$$\Pi^{NL}_{P_i} = \lambda^{NL}_i(1)\pi + \delta\Pi^{NL}_{P_i}$$

Licensing will occur in equilibrium if and only if there exist values of $X^L$ that satisfy

$$\Pi^L_T(X^L) \geq \Pi^{NL}_T$$  \hspace{1cm} (6)$$

and

$$\Pi^L_{P_i}(X^L) \geq \Pi^{NL}_{P_i}$$  \hspace{1cm} (7)$$

Substituting the values from above, this means $T$ will offer $X^L$ such that:

$$X^L \geq c_i + \lambda^{NL}_T(1)\pi$$

Meanwhile, $P_i$ will agree to license if

$$X^L \leq 2\lambda_1(1)\pi - \lambda^{NL}_P(1)\pi$$

Hence, under this scenario licensing will occur in equilibrium if and only if

$$c_i \leq 2\lambda_1(1)\pi - \lambda^{NL}_P(1)\pi - \lambda^{NL}_T(1)\pi$$  \hspace{1cm} (8)$$

3.2.2 Equilibrium strategies with experiential learning

We now allow for the possibility of experiential learning. In this context, experiential learning means that if $T$ successfully commercializes an innovation (through its own efforts) then $\sigma_T$ rises from $\sigma^{NL}_T$ to $\sigma^{NL'}_T$. Therefore $T$’s expected discounted profits from not licensing will be different before and after it has commercialized an innovation. We let $\Pi^{NL}_T$ be $T$’s expected discounted profits before it has commercialized an innovation and $\Pi^{NL'}_T$ be $P$’s expected discounted profits after $T$ has done so. With experiential learning, $\Pi^{NL}_T$ and $\Pi^{NL'}_T$ will be
Solving these equations for $\Pi_T^{NL}$ gives

$$\Pi_T^{NL} = \frac{\lambda_1(1) \pi}{1 - \delta}$$

$$\Pi_T^{NL} = \frac{\lambda_T^{NL}(1) \pi + \sigma_T^{NL} \frac{\delta}{1 - \delta} \lambda_1(1) \pi}{1 - \delta(1 - \sigma_T^{NL})}$$

Meanwhile, with experiential learning, $\Pi_{P_i}^{NL}$ and $\Pi_{P_i}^{NL'}$ are

$$\Pi_{P_i}^{NL} = \lambda_{P_i}^{NL}(1) \pi + \sigma_{P_i}^{NL} \delta \Pi_{P_i}^{NL'} + (1 - \sigma_{P_i}^{NL}) \delta \Pi_{P_i}^{NL}$$

$$\Pi_{P_i}^{NL'} = \lambda_{P_i}^{NL'}(1) \pi + \delta \Pi_{P_i}^{NL'}$$

Solving for $\Pi_{P_i}^{NL}$ gives

$$\Pi_{P_i}^{NL} = \frac{\lambda_{P_i}^{NL}(1) \pi}{1 - \delta}$$

$$\Pi_{P_i}^{NL} = \frac{\lambda_{P_i}^{NL}(1) + \frac{\delta}{1 - \delta} \sigma_{P_i}^{NL} \lambda_1(1)}{1 - \delta(1 - \sigma_{P_i}^{NL})} \pi$$

As above, licensing will be an equilibrium if there exists a $X^L$ that satisfies equations (6) and (7) respectively. That is

$$X^L \geq c_i + \frac{1 - \delta}{1 - \delta(1 - \sigma_T^{NL})} \left[ \lambda_T^{NL}(1) \pi + \frac{\delta}{1 - \delta} \sigma_T^{NL} \lambda_1(1) \pi \right]$$

and

$$X^L \leq 2\lambda_1(1) \pi - \frac{1 - \delta}{1 - \delta(1 - \sigma_T^{NL})} \left[ \lambda_{P_i}^{NL}(1) \pi + \sigma_{P_i}^{NL} \frac{\delta}{1 - \delta} \lambda_1(1) \pi \right]$$
Under this scenario licensing will occur in equilibrium if and only if

\[
c_i \leq \frac{1 - \delta}{1 - \delta(1 - \sigma_{NL}^{T})} \left[ 2\lambda_1(1)\pi - \lambda_{NL}^{T}(1)\pi - \lambda_{NL}^{T}(1)\pi \right]
\]  

(9)

### 3.2.3 Equilibrium strategies with co-promotion

We now introduce the option of co-promotion. For convenience, we set \( N = 1 \) and \( \phi = 1 \) but will relax these assumptions later. Under co-promotion, \( T \) licenses its innovation to \( P \) but retains the right to participate in commercialization, meaning that if the commercialization is concluded successfully then \( T \) gets the opportunity to co-promote the product and thereby acquires knowledge of the commercialization process. As a consequence, \( \sigma_{NL}^{T} \) rises to \( \sigma_{NL}^{T'} \) for all subsequent innovations.

Let \( \Pi_T^{CP} \) denote the present value of \( T \)'s expected profits from a co-promotion arrangement before \( T \) has commercialized an innovation successfully and \( \Pi_T^{CP'} \) denote the value after it has successfully commercialized an innovation. The value of \( \Pi_T^{CP} \) is given by

\[
\Pi_T^{CP} = X_T^{CP} - c_i + \sigma_T^{CP} \delta \Pi_T^{CP'} + (1 - \sigma_T^{CP}) \delta \Pi_T^{CP}
\]

After \( T \) has successfully commercialized an innovation under a co-promotion arrangement, it has the same probability of commercialization as any potential product-firm partner and hence it will (weakly) prefer to not license the innovation but to develop the product alone. Hence \( \Pi_T^{CP'} = \Pi_T^{NL} \)

Substituting in value of \( \Pi_T^{NL} \) gives

\[
\Pi_T^{CP} = \frac{X_T^{CP} - c_i + \frac{\delta}{1 - \sigma_T^{CP}} \lambda_{11}(1)\pi}{1 - \delta(1 - \sigma_T^{CP})}
\]

Now let \( \Pi_{T_i}^{CP} \) be the present value of \( P_i \)'s expected profits before \( T \) and \( P \) have successfully commercialized an innovation in a co-promotion arrangement and \( \Pi_{T_i}^{CP'} \) be the same after. The value of \( \Pi_{T_i}^{CP} \) is given by
\[ \Pi_{CP}^{T} = \lambda_{T}^{CP} (1)\pi + \lambda_{P}^{CP} (1)\pi - X^{CP} + \sigma_{T}^{CP} \delta \Pi_{P}^{CP} + \left(1 - \sigma_{T}^{CP}\right) \delta \Pi_{P}^{CP} \]

Since \( T \) will prefer not to license after it has successfully commercialized an innovation (as above),
\[ \Pi_{CP}^{T} = \Pi_{NL}^{T} \text{. Substituting } \Pi_{NL}^{T} \text{ for } \Pi_{CP}^{T} \text{ gives} \]
\[ \Pi_{CP}^{T} = \frac{\lambda_{T}^{CP} (1)\pi - X^{CP} + \lambda_{P}^{CP} (1)\pi + \frac{\delta}{1-\delta} \sigma_{T}^{CP} \lambda_{i1} (1)\pi}{1-\delta \left(1-\sigma_{T}^{CP}\right)} \]

Co-promotion will occur in equilibrium, if and only if it is preferred to both licensing and not licensing - that is, if there are values of \( X^{CP} \) that satisfy the following conditions:
\[
\begin{align*}
\Pi_{CP}^{T} (X^{CP}) &\geq \Pi_{P}^{T} (X^{L}) \quad (10) \\
\Pi_{CP}^{T} (X^{CP}) &\geq \Pi_{NL}^{T} \quad (11) \\
\Pi_{P}^{T} (X^{CP}) &\geq \Pi_{P}^{T} (X^{L}) \quad (12) \\
\Pi_{P}^{T} (X^{CP}) &\geq \Pi_{NL}^{T} \quad (13)
\end{align*}
\]

We consider these one by one.

**Co-promotion vs. Licensing**

First we consider the choice between co-promotion and licensing. \( T \) will prefer co-promotion to licensing if
\[
X^{CP} \geq \frac{1-\delta \left(1-\sigma_{T}^{CP}\right)}{1-\delta} X^{L} - \frac{\delta \sigma_{T}^{CP}}{1-\delta} (c_{i} + \lambda_{i1} (1)\pi)
\]

Meanwhile, \( P_{i} \) will prefer co-promotion to licensing if
\[
X^{CP} \leq \frac{1-\delta \left(1-\sigma_{T}^{CP}\right)}{1-\delta} X^{L} + \lambda_{T}^{CP} (1)\pi + \lambda_{P}^{CP} (1)\pi - \frac{1-\delta \left(1-\frac{1}{2} \sigma_{T}^{CP}\right)}{1-\delta} \lambda_{i1} (1)\pi
\]

Hence the parties will choose co-promotion over licensing in equilibrium if and only if
Now we consider the choice between co-promotion and not licensing/self-commercialization. 

\[ T \] will prefer co-promotion to not licensing/self-commercialization if 
\[
X^{CP} \geq c_i \cdot \left(1 - \frac{1 - \delta \left(1 - \sigma_{CP}^{\lambda} \right)}{1 - \delta \left(1 - \sigma_{NL}^{\lambda} \right)} \lambda_{T}^{NL}(1) \pi - \frac{\delta \left(\lambda_{P}^{CP} - \lambda_{P}^{NL} \right)}{1 - \delta \left(1 - \sigma_{NL}^{\lambda} \right)} \lambda_{i}^{\lambda}(1) \pi \right)
\]

Meanwhile, \[ P \] will be willing to enter a co-promotion arrangement, rather than letting \[ T \] commercialize alone, if 
\[
X^{CP} \leq \lambda_{T}^{CP}(1) \pi + \lambda_{P}^{CP}(1) \pi - \frac{1 - \delta \left(1 - \sigma_{CP}^{\lambda} \right)}{1 - \delta \left(1 - \sigma_{NL}^{\lambda} \right)} \lambda_{T}^{NL}(1) \pi + \frac{\delta \left(\lambda_{P}^{CP} - \lambda_{P}^{NL} \right)}{1 - \delta \left(1 - \sigma_{NL}^{\lambda} \right)} \lambda_{i}^{\lambda}(1) \pi
\]

Hence the parties will choose co-promotion over not licensing/self-commercialization if 
\[
c_i \leq 2 \frac{\delta \left(\lambda_{P}^{CP} - \lambda_{P}^{NL} \right)}{1 - \delta \left(1 - \sigma_{NL}^{\lambda} \right)} \lambda_{i}^{\lambda}(1) \pi + \lambda_{P}^{CP}(1) \pi + \lambda_{P}^{NL}(1) \pi - \frac{1 - \delta \left(1 - \sigma_{CP}^{\lambda} \right)}{1 - \delta \left(1 - \sigma_{NL}^{\lambda} \right)} \lambda_{i}^{\lambda}(1) \pi
\]

When \[ \phi \leq 1 \]

\[ 3.2.4 \quad \text{Equilibrium strategies when } \phi \leq 1 \]

Now we relax the assumption that \( T \) innovates the product field in every period and allow \( \phi \leq 1 \). To solve the case with \( \phi < 1 \), we need to also consider the scenario where \( T \) does not innovate in the product field in a particular field. Let \( \Pi^{0}_{T} \) be the present value of its discounted profits in the scenario where does not innovate in the field. The values of \( \Pi^{L}_{T} \), \( \Pi^{NL}_{T} \) and \( \Pi^{CP}_{T} \) under this scenario are given by

\[
\Pi^{L}_{T} = X^{L} - c_i + \delta \left[ \phi \Pi^{L}_{T} + (1 - \phi) \Pi^{0}_{T} \right]
\]

\[
\Pi^{NL}_{T} = \lambda_{T}^{NL}(1) \pi + \delta \left[ \phi \left[ \lambda_{T}^{NL} \Pi^{NL}_{T} + (1 - \sigma_{P}^{NL}) \Pi^{NL}_{T} \right] + (1 - \phi) \Pi^{0}_{T} \right]
\]

\[
\Pi^{CP}_{T} = X^{CP} - c_i + \delta \left[ \phi \left[ \lambda_{P}^{CP} \Pi^{CP}_{T} + (1 - \sigma_{P}^{CP}) \Pi^{CP}_{T} \right] + (1 - \phi) \Pi^{0}_{T} \right]
\]
\[ \Pi_T^{NL} = \lambda_T^{NL} (1)\pi + \delta\left[ \phi \Pi_T^{NL} + (1-\phi)\Pi_T^0 \right] \]

\[ \Pi_T^0 = 0 + \delta\left[ \phi \Pi_T^S + (1-\phi)\Pi_T^0 \right] \]

where \( S \in \{L, NL, CP, NL'\} \)

Solving these equations gives

\[ \Pi_T^0 = \frac{\delta\phi}{1 - \delta(1-\phi)} \Pi_T^S \]

\[ \Pi_T^c = \frac{1 - \delta(1-\phi)}{1 - \delta} (X^L - c_i) \]

\[ \Pi_T^{NL'} = \frac{1 - \delta(1-\phi)}{1 - \delta} \lambda_{11}(1)\pi \]

\[ \Pi_T^{NL} = \frac{1 - \delta(1-\phi)}{1 - \delta + \delta\phi\sigma_T^{NL} (1-\delta(1-\phi))} \lambda_T^{NL} (1)\pi + \frac{\delta}{1 - \delta + \delta\phi\sigma_T^{NL} (1-\delta(1-\phi))} \lambda_{11}(1)\pi \]

\[ \Pi_T^{CP} = \frac{1 - \delta + \delta\phi}{1 - \delta + \delta\phi\sigma_T^{CP} (1-\delta + \delta\phi)} (X^{CP} - c_i) + \frac{\delta}{1 - \delta + \delta\phi\sigma_T^{CP} (1-\delta + \delta\phi)} \lambda_{11}(1)\pi \]

Let \( \Pi_T^0 \) be \( P_i \)'s present value of the expected profits when \( T \) does not innovate in the field. The values of \( \Pi_T^L, \Pi_T^{NL}, \Pi_T^{CP}, \Pi_T^{CP'}, \Pi_T^{NL'}, \) and \( \Pi_T^0 \) are given by

\[ \Pi_T^L = \lambda_T^L (1)\pi - X^L + \phi \left( \frac{1}{N} \Pi_T^L + \frac{N-1}{N} \Pi_T^{L'} \right) + (1-\phi)\Pi_T^0 \]

\[ \Pi_T^{NL} = \lambda_T^{NL} (1)\pi + \delta \left( \phi \left[ \sigma_T^{NL} \Pi_T^{NL} + (1-\sigma_T^{NL})\Pi_T^{NL} \right] + (1-\phi)\Pi_T^0 \right) \]

\[ \Pi_T^{CP} = \lambda_T^{CP} (1)\pi - X^{CP} + \phi \left( \sigma_T^{CP} \Pi_T^{CP} + (1-\sigma_T^{CP})\Pi_T^{CP} \right) + (1-\phi)\Pi_T^0 \]
\[
\Pi_{P_{i}}^{NL} = \lambda_{\eta_{i}}^{NL} (1)\pi + \delta \left[ \phi \Pi_{P_{i}}^{NL} + (1 - \phi) \Pi_{P_{i}}^{\theta} \right]
\]

\[
\Pi_{P_{i}}^{\theta} = \lambda_{\eta_{i}}^{\theta} (1)\pi + \delta \left[ \phi \Pi_{P_{i}}^{\theta} + (1 - \phi) \Pi_{P_{i}}^{\theta} \right]
\]

where \( S \in \{L, NL\} \)

As above, we can let \( \Pi_{P_{i}}^{CP} = \Pi_{P_{i}}^{NL} \).

Solving these equations gives

\[
\Pi_{P_{i}}^{\theta} = \frac{\lambda_{\eta_{i}}^{\theta} (1)\pi + \delta \phi \Pi_{P_{i}}^{S}}{1 - \delta (1 - \phi)}
\]

where \( \Pi_{P_{i}}^{S} = \Pi_{P_{i}}^{S} \) if \( S = NL \)

\[
\Pi_{P_{i}}^{L} = \frac{1 - \delta (1 - \phi)}{1 - \delta} \left( \lambda_{\eta_{i}}^{L} (1)\pi - X^{L} + \lambda_{\eta_{i}}^{L} (1)\pi \right) + \frac{\delta (1 - \phi)}{1 - \delta} \lambda_{\eta_{i}}^{\theta} (1)\pi
\]

\[
\Pi_{P_{i}}^{NL} = \frac{1 - \delta (1 - \phi)}{1 - \delta} \lambda_{\eta_{i}}^{NL} (1)\pi + \frac{\delta (1 - \phi)}{1 - \delta} \lambda_{\eta_{i}}^{\theta} (1)\pi
\]

\[
\Pi_{P_{i}}^{CP} = \frac{1 - \delta (1 - \phi)}{1 - \delta + \delta \phi \sigma_{\eta_{i}}^{CP} (1 - \delta (1 - \phi))} \left( \lambda_{\eta_{i}}^{CP} (1)\pi - X^{CP} + \lambda_{\eta_{i}}^{CP} (1)\pi \right)
\]

\[
+ \frac{\delta}{1 - \delta} \frac{(1 - \delta (1 - \phi))^2}{1 - \delta + \delta \phi \sigma_{\eta_{i}}^{CP} (1 - \delta (1 - \phi))} \lambda_{\eta_{i}}^{NL} (1)\pi + \frac{\delta (1 - \phi)}{1 - \delta} \lambda_{\eta_{i}}^{\theta} (1)\pi
\]

**Licensing vs. Not licensing/Self-commercialization**

Using the formula in(6), we show that licensing will be an equilibrium if

\[
X^{L} \geq c_{i} + \frac{1 - \delta}{1 - \delta + \delta \phi \sigma_{\eta_{i}}^{NL} (1 - \delta (1 - \phi))} \lambda_{\eta_{i}}^{NL} (1)\pi + \frac{\delta \phi \sigma_{\eta_{i}}^{NL} (1 - \delta (1 - \phi))}{1 - \delta + \delta \phi \sigma_{\eta_{i}}^{NL} (1 - \delta (1 - \phi))} \lambda_{\eta_{i}}^{\theta} (1)\pi
\]

and, from (7), if
\[ X^L \leq \left( 1 + \frac{1 - \delta}{1 - \delta \left( 1 - \delta \phi \sigma_{rNL} \left( 1 - \delta (1 - \phi) \right) \right)} \right) \lambda_{i1}(1) \pi - \frac{1 - \delta}{1 - \delta \left( 1 - \delta \phi \sigma_{rNL} \left( 1 - \delta (1 - \phi) \right) \right)} \lambda_{r1}^{NL}(1) \pi \]

Under this scenario licensing will occur in equilibrium if and only if

\[ c_i \leq \frac{1 - \delta}{1 - \delta \left( 1 - \delta \phi \sigma_{rNL} \left( 1 - \delta (1 - \phi) \right) \right)} \left( 2 \lambda_{i1}(1) \pi - \lambda_{r1}^{NL}(1) \pi - \lambda_{r1}^{NL}(1) \pi \right) \]  

(16)

**Co-promotion vs. Licensing**

\( T \) will prefer co-promotion to licensing if

\[ X^{CP} \geq \frac{1 - \delta + \delta \phi \sigma_{rCP} \left( 1 - \delta + \delta \phi \right)}{1 - \delta} X^L - \frac{\delta \phi \sigma_{rCP} \left( 1 - \delta + \delta \phi \right)}{1 - \delta} \left( \lambda_{i1}(1) \pi + c_i \right) \]

Meanwhile, \( P_i \) will prefer co-promotion to licensing if

\[ X^{CP} \leq \lambda_{r1}^{CP}(1) \pi + \lambda_{r1}^{CP}(1) \pi + \frac{\delta}{1 - \delta} \phi \sigma_{rCP} \left( 1 - \delta \left( 1 - \phi \right) \right) \lambda_{r1}^{NL}(1) \pi \]

\[ - \frac{1 - \delta + \delta \phi \sigma_{rCP} \left( 1 - \delta \left( 1 - \phi \right) \right)}{1 - \delta} \left( \lambda_{r1}^{CP}(1) \pi - X^L + \lambda_{i1}^{CP}(1) \pi \right) \]

Hence the parties will choose co-promotion over licensing in equilibrium if and only if

\[ c_i \geq \frac{1 - \delta}{\delta \phi \sigma_{rCP} \left( 1 - \delta + \delta \phi \right)} \left( 2 \lambda_{i1}(1) \pi - \lambda_{r1}^{CP}(1) \pi - \lambda_{r1}^{CP}(1) \pi \right) \]  

(17)

**Co-promotion vs. Not Licensing/Self-commercialization**

Now we consider the choice between co-promotion and not licensing/self-commercialization.

\( T \) will prefer co-promotion to not licensing/self-commercialization if

\[ X^{CP} \geq c_i + \frac{1 - \delta + \delta \phi \sigma_{rCP} \left( 1 - \delta + \delta \phi \right)}{1 - \delta + \delta \phi \sigma_{rNL} \left( 1 - \delta + \delta \phi \right)} \lambda_{r1}^{NL}(1) \pi \]

\[ - \frac{\delta \phi \left( 1 - \delta \left( 1 - \phi \right) \right)}{1 - \delta} \left( \sigma_{rCP}^{CP} - \frac{1 - \delta + \delta \phi \sigma_{rCP} \left( 1 - \delta + \delta \phi \right)}{1 - \delta + \delta \phi \sigma_{rCP} \left( 1 - \delta + \delta \phi \right)} \sigma_{rNL}^{CP} \right) \lambda_{i1}(1) \pi \]
Meanwhile, $P$ will be willing to enter a co-promotion arrangement, rather than letting $T$ commercialize alone, if

$$X^{CP} \leq \lambda_T^{CP}(1)\pi + \lambda_{P_i}^{CP}(1)\pi - \frac{1 - \delta + \delta \phi \sigma_T^{CP} (1 - \delta (1 - \phi))}{1 - \delta + \delta \phi \sigma_T^{NL} (1 - \delta (1 - \phi))} \lambda_T^{NL}(1)\pi$$

$$+ \frac{\delta}{1 - \delta} \phi (1 - \delta (1 - \phi)) \left( \sigma_T^{CP} - \frac{1 - \delta + \delta \phi \sigma_T^{CP} (1 - \delta (1 - \phi))}{1 - \delta + \delta \phi \sigma_T^{NL} (1 - \delta (1 - \phi))} \sigma_T^{NL} \right) \lambda_{P_i}(1)\pi$$

Hence the parties will choose co-promotion over not licensing/self-commercialization if

$$c_i \leq 2 \frac{\delta \phi (1 - \delta (1 - \phi))}{1 - \delta + \delta \phi \sigma_T^{NL} (1 - \delta (1 - \phi))} \left( \sigma_T^{CP} - \sigma_T^{NL} \right) \lambda_{P_i}(1)\pi + \lambda_T^{CP}(1)\pi + \lambda_{P_i}^{CP}(1)\pi$$

$$- \frac{1 - \delta + \delta \phi \sigma_T^{CP} (1 - \delta + \delta \phi)}{1 - \delta + \delta \phi \sigma_T^{NL} (1 - \delta + \delta \phi)} \left( \lambda_T^{NL}(1)\pi + \lambda_{P_i}^{NL}(1)\pi \right)$$

(18)

3.2.5 Equilibrium strategies with $N > 1$

Now, in the alternative, we allow for $N > 1$, meaning $T$ negotiates with multiple product firms to commercialize $T$’s innovation. At the same time, we set $\phi = 1$, so that $T$ always generates an innovation in the particular product field.

From $T$’s perspective, the scenario with $N > 1$ is no different than when $N = 1$ since all product firms are identical. If it is an equilibrium for $T$ to license (or co-promote) then it randomly chooses a product firm $P_i$ with which to execute the transaction. However, from $P_i$’s perspective this case is different because even if it is an equilibrium for $T$ to license (or co-promote) it is not necessarily the case that $P_i$ is the licensor. Therefore we need to consider $P_i$’s payoffs under the scenario where $T$ licenses its innovation to a firm other than $P_i$. Hence, let $\Pi_{P_i}^L$ and $\Pi_{P_i}^{CP}$ be the present value of $P_i$’s expected profits when $T$ licenses the product to another product firm and when $T$ enters a co-promotion arrangement with another product firm $P_{-i}$, respectively.

Nevertheless, since $T$ will always (weakly) prefer to commercialize the innovation after it has acquired specialized commercialization capabilities, we only need to consider this additional case for the situation before $T$ has successfully commercialized an innovation.
The values of $\Pi_T^L$, $\Pi_T^{CP}$, $\Pi_T^{NL}$ and $\Pi_T^{NL'}$ under this scenario are given by

$$\Pi_T^L = X^L - c_i + \delta \Pi_T^L$$

$$\Pi_T^{CP} = X^{CP} - c_i + \delta \left[ \sigma_T^{CP} \delta \Pi_T^{CP} + (1 - \sigma_T^{NL}) \Pi_T^{CP} \right]$$

$$\Pi_T^{NL} = \lambda_T^{NL} (N)\pi + \delta \left[ \sigma_T^{NL} \Pi_T^{NL} + (1 - \sigma_T^{NL}) \Pi_T^{NL} \right]$$

$$\Pi_T^{NL'} = \lambda_T^{NL'} (N)\pi + \delta \Pi_T^{NL'}$$

where $S \in \{L, NL, CP, NL'\}$

As above, we can let $\Pi_T^{CP'} = \Pi_T^{NL'}$.

Solving these equations gives

$$\Pi_T^L = \frac{X^L - c_i}{1 - \delta}$$

$$\Pi_T^{NL'} = \frac{\lambda_T^{NL'} (N)\pi}{1 - \delta}$$

$$\Pi_T^{NL} = \frac{\lambda_T^{NL} (N)\pi + \frac{\delta}{1 - \delta} \sigma_T^{NL} \lambda_T^{NL'} (N)\pi}{1 - \delta (1 - \sigma_T^{NL})}$$

$$\Pi_T^{CP} = \frac{X^{CP} - c_i + \delta \sigma_T^{CP} \lambda_T^{NL'} (N)\pi}{1 - \delta (1 - \sigma_T^{CP})}$$

The values of $\Pi_{p_i}^L$, $\Pi_{p_i}^{L'}$, $\Pi_{p_i}^{CP}$, $\Pi_{p_i}^{CP'}$, $\Pi_{p_i}^{NL}$, and $\Pi_{p_i}^{NL'}$ are given by

$$\Pi_{p_i}^L = \lambda_{p_i}^L (N)\pi - X^L + \lambda_{p_i}^L (N)\pi + \delta \left( \frac{1}{N} \Pi_{p_i}^L + \frac{N-1}{N} \Pi_{p_i}^{L'} \right)$$

$$\Pi_{p_i}^{L'} = \lambda_{p_i}^{L'} (N)\pi + \delta \left( \frac{1}{N} \Pi_{p_i}^L + \frac{N-1}{N} \Pi_{p_i}^{L'} \right)$$
\[
\Pi_{P_i}^{CP} = \lambda_{P_i}^{CP}(N)\pi - X^{CP} + \lambda_{P_i}^{CP}(N)\pi + \delta \left[ \sigma_T^{CP} \Pi_T^{CP} + \left( 1 - \sigma_T^{CP} \right) \left( \frac{1}{N} \Pi_{P_i}^{CP} + \frac{N-1}{N} \Pi_{P_{i-1}}^{CP} \right) \right]
\]

\[
\Pi_{P_{i-1}}^{CP} = \lambda_{P_{i-1}}^{CP}(N)\pi + \delta \left[ \sigma_T^{CP} \Pi_T^{CP} + \left( 1 - \sigma_T^{CP} \right) \left( \frac{1}{N} \Pi_{P_i}^{CP} + \frac{N-1}{N} \Pi_{P_{i-1}}^{CP} \right) \right]
\]

\[
\Pi_{P_i}^{NL} = \lambda_{P_i}^{NL}(N)\pi + \delta \left[ \sigma_T^{NL} \Pi_T^{NL} + \left( 1 - \sigma_T^{NL} \right) \Pi_{P_i}^{NL} \right]
\]

\[
\Pi_{P_{i-1}}^{NL} = \lambda_{P_{i-1}}^{NL}(N)\pi + \delta \Pi_{P_i}^{NL}
\]

Setting \( \Pi_{P_{i-1}}^{CP} = \Pi_{P_i}^{NL} \) and solving these equations gives

\[
\Pi_{P_{i-1}}^{L} = \frac{N\lambda_{P_{i-1}}^{L}(N)\pi + \delta \Pi_{P_{i-1}}^{L}}{N - \delta(N-1)}
\]

\[
\Pi_{P_i}^{L} = \frac{N - \delta(N-1)}{N(1-\delta)} \left( \lambda_{P_i}^{L}(N)\pi - X^{L} \right) + \frac{1}{1-\delta} \lambda_{P_i}^{L}(N)\pi
\]

\[
\Pi_{P_i}^{NL} = \frac{\lambda_{P_i}^{NL}(N)\pi + \frac{\delta}{1-\delta} \sigma_T^{NL} \lambda_{P_i}^{NL}(N)\pi}{1-\delta(1-\sigma_T^{NL})}
\]

\[
\Pi_{P_{i-1}}^{NL} = \frac{N \left( \lambda_{P_{i-1}}^{CP}(N)\pi + \frac{\delta}{1-\delta} \sigma_T^{CP} \lambda_{P_{i-1}}^{NL}(N)\pi \right) + \delta \left( 1 - \sigma_T^{CP} \right) \Pi_{P_{i-1}}^{CP}}{N - \delta(1 - \sigma_T^{CP})(N-1)}
\]

\[
\Pi_{P_i}^{CP} = \frac{\left( N - \delta(1 - \sigma_T^{CP})(N-1) \right) \left( \lambda_{P_i}^{CP}(N)\pi - X^{CP} + \lambda_{P_i}^{CP}(N)\pi \right)}{N \left( 1 - \delta(1 - \sigma_T^{CP}) \right)}
\]

\[
+ \frac{\delta}{1-\delta} \frac{N \sigma_T^{CP} \lambda_{P_{i-1}}^{NL}(N)\pi + \delta(1 - \sigma_T^{CP})(N-1) \lambda_{P_{i-1}}^{CP}(N)\pi}{N \left( 1 - \delta(1 - \sigma_T^{CP}) \right)}
\]
Licensing vs. Not-licensing/Self-commercialization

Licensing will be an equilibrium if

\[
X^L \geq c_i - \frac{1-\delta}{1-\delta(1-\sigma_T^{NL})} \lambda_T^{NL}(N) + \frac{\delta}{1-\delta(1-\sigma_T^{NL})} \sigma_T^{NL} \lambda_T^{NL}(N) \pi
\]

\[
X^L \leq \frac{(2N-\delta(N-1))(1-\delta)+\delta \sigma_T^{NL}(N-\delta(N-1))}{(N-\delta(N-1))(1-\delta(1-\sigma_T^{NL}))} \lambda_1(N) \pi
\]

and

\[
-\frac{(1-\delta)N}{(1-\delta(1-\sigma_T^{NL}))(N-\delta(N-1))} \lambda_{\Pi_T}^{NL}(N) \pi
\]

Under this scenario licensing will occur in equilibrium if and only if

\[
c_i \leq \frac{1-\delta}{1-\delta(1-\sigma_T^{NL})} \left( \lambda_1(N) \pi - \lambda_T^{NL}(N) + \frac{N}{N-\delta(N-1)} \left( \lambda_1(N) \pi - \lambda_{\Pi_T}^{NL}(N) \pi \right) \right)
\]

(19)

Co-promotion vs. Licensing

\( T \) will prefer co-promotion to licensing if

\[
X^{CP} \geq \frac{1-\delta}{1-\delta(1-\sigma_T^{CP})} X^L - \frac{\delta}{1-\delta(1-\sigma_T^{CP})} \left( c_i + \lambda_T^{NL}(N) \pi \right)
\]

Meanwhile, \( P_T \) will prefer co-promotion to licensing if

\[
X^{CP} \leq \lambda_T^{CP}(N) \pi + \lambda_{\Pi_T}^{CP}(N) \pi - \frac{(1-\delta)(1-\sigma_T^{CP})}{(1-\delta)(N-\delta(N-1))} \lambda_1(N) \pi
\]

\[
+ \frac{\delta(1-\sigma_T^{CP})(N-1)}{N-\delta(1-\sigma_T^{CP})(N-1)} \lambda_{\Pi_T}^{CP}(N) \pi + \frac{1-\delta(1-\sigma_T^{CP})}{1-\delta} \frac{N-\delta(N-1)}{N-\delta(1-\sigma_T^{CP})(N-1)} X^L
\]

Hence the parties will choose co-promotion over licensing in equilibrium if and only if

\[
c_i \leq \frac{(1-\delta)(1-\sigma_T^{CP})(N-1)}{N-\delta(1-\sigma_T^{CP})(N-1)} X^L + \frac{2N(1-\delta)-\delta(N-1)(1-\delta+\delta \sigma_T^{CP})}{\delta \sigma_T^{CP} \left( N-\delta \left( 1-\sigma_T^{CP} \right)(N-1) \right)} \lambda_1(N) \pi
\]

\[
+ \frac{(1-\delta)(1-\sigma_T^{CP})(N-1)}{\sigma_T^{CP} \left( N-\delta(1-\sigma_T^{CP})(N-1) \right)} \lambda_{\Pi_T}^{CP}(N) \pi - \frac{1-\delta}{\delta \sigma_T^{CP} \left( \lambda_T^{CP}(N) \pi + \lambda_{\Pi_T}^{CP}(N) \pi \right)}
\]

(20)
Co-promotion vs. Not Licensing/Self-commercialization

Now we consider the choice between co-promotion and not licensing/self-commercialization.

\[ T \] will prefer co-promotion to not licensing/self-commercialization if

\[ X^{CP} \geq c_i - \frac{\delta \left( \sigma_{T}^{CP} - \sigma_{T}^{NL} \right)}{1 - \delta \left( 1 - \sigma_{T}^{NL} \right)} \lambda_{T}^{NL} (N) \pi + \frac{1 - \delta \left( 1 - \sigma_{T}^{CP} \right)}{1 - \delta \left( 1 - \sigma_{T}^{NL} \right)} \lambda_{T}^{NL} (N) \pi \]

Meanwhile \( P \) will be willing to enter a co-promotion arrangement, rather than letting \( T \) commercialize alone, if

\[ X^{CP} \leq \lambda_{T}^{CP} (N) \pi + \lambda_{P}^{CP} (N) \pi + \frac{\delta N \left( \sigma_{T}^{CP} - \sigma_{T}^{NL} \right)}{1 - \delta \left( 1 - \sigma_{T}^{NL} \right) \left( (N - \delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1) \right)} \lambda_{T}^{NL} (N) \pi \\
- \left[ 1 - \delta \left( 1 - \sigma_{T}^{NL} \right) \left( (N - \delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1) \right) \right] \lambda_{P}^{NL} (N) \pi \\
+ \frac{\delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1)}{N - \delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1)} \lambda_{P}^{CP} (N) \pi \]

Hence the parties will choose co-promotion over not licensing/self-commercialization if

\[ c_i \leq \lambda_{T}^{CP} (N) \pi + \lambda_{P}^{CP} (N) \pi + \frac{\delta \left( \sigma_{T}^{CP} - \sigma_{T}^{LN} \right) \left( 2 N - \left( 1 - \sigma_{T}^{CP} \right) (N - 1) \right)}{1 - \delta \left( 1 - \sigma_{T}^{NL} \right) \left( (N - \delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1) \right)} \lambda_{T}^{NL} (N) \pi \\
- \frac{1 - \delta \left( 1 - \sigma_{T}^{CP} \right)}{1 - \delta \left( 1 - \sigma_{T}^{NL} \right)} \left[ \lambda_{T}^{NL} (N) \pi - \frac{N}{\left( (N - \delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1) \right)} \lambda_{P}^{NL} (N) \pi \right] \\
+ \frac{\delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1)}{N - \delta \left( 1 - \sigma_{T}^{CP} \right) (N - 1)} \lambda_{P}^{CP} (N) \pi \]

3.3 Propositions derived from the model

We now use the model to derive a number of propositions. The proofs are presented in the Appendix.

The first result -- presented here as a lemma -- replicates the basic prediction of Teece (1986):
Lemma 1 In a technology commercialization game without experiential learning and only one product firm, licensing will be the unique equilibrium if the product firm is better positioned with respect to the complementary assets (i.e., $\sigma_{NL}^{P_i} > \sigma_{NL}^{T}$) and transaction costs ($c_t$) are sufficiently low.

We now show that in a technology commercialization game with experiential learning, not licensing will be an equilibrium outcome even in cases where it would not be an equilibrium without experiential learning.

Lemma 2 Not licensing is more likely to be an equilibrium outcome in a technology commercialization game with experiential learning than in a game without experiential learning.

Lemma 2 demonstrates that, if the technology firm has the opportunity to learn from its own experience, it may decide not to license the innovation and instead to commercialize the innovation alone. Moreover, this does not incorporate the possibility that the product firm may also learn from its experience in commercialization. As Pisano (1991) argued, if in the process of commercializing the innovation $P_i$ develops specialized knowledge about the commercialization process or the product markets which increases its capabilities to commercialize future innovations, $P_i$ may be in an even stronger bargaining position (relative to both the technology firm and other product firms) in future negotiations to commercialize an innovation. Hence $T$ may have an even stronger motivation to attempt to commercialize its own innovation.

Proposition 1 states the conditions under which not licensing (or commercializing alone) is more likely to be preferred to licensing.

Proposition 1 In a technology commercialization game with experiential learning (a) the likelihood that licensing is an equilibrium outcome is decreasing in $\phi$; (b) the likelihood that licensing is an equilibrium outcome is decreasing in $N$.

Nevertheless, commercializing alone is expensive and the technology firm's inexperience means that there is a higher risk of failure than if it licenses the innovation with a product firm. It follows therefore that a hybrid arrangement of two base strategies may be preferable under certain circumstances. Proposition 2 sets out the conditions under which co-promotion will be an equilibrium outcome, and the parameter values that are more likely to make it so.

Lemma 3 In the technology commercialization game with experiential learning where $N=1$ and $\phi=1$, co-promotion is an equilibrium outcome if $\sigma_{NL}^{P_i} = \sigma_{NL}^{T} = \sigma_{NL}^{P_i} = \sigma_{NL}^{T} = \sigma_1$.
\[ \sigma^{NL}_T = \sigma^*_0 < \sigma^*_1, \sigma^{CP}_T = \frac{1}{2}(\sigma^*_0 + \sigma^*_1), \text{and } \sigma^*_1 \geq \frac{1-\delta}{\delta} \]. More generally, co-promotion is an equilibrium outcome if

\[
\frac{1 - \delta(1 - \sigma^{CP}_T)}{1 - \delta(1 - \sigma^{NL}_T)} \left( \sigma^{NL}_{\gamma} \left( 1 - \frac{1}{2} \sigma^{NL}_{\beta} \right) \left( \delta ( \sigma^{CP}_T - \sigma^{NL}_T ) - (1 - \delta) \right) \right)
\]

\[
-\delta \sigma^{CP}_T \left( \sigma^{NL}_T - \sigma^{NL}_T \sigma^{NL}_T + \sigma^{NL}_{\gamma} \right) + (1 - \delta(1 - \sigma^{NL}_T)) \left( \sigma^{CP}_T - \sigma^{CP}_T \sigma^{CP}_T + \sigma^{CP}_{\gamma} \right) \right) \pi \geq 0
\]

**Proposition 2** The likelihood that \( T \) and \( P_l \) will agree to a co-promotion rather than a pure licensing arrangement is increasing in \( \phi \).

### 4. Empirical analysis

Having derived the conditions under which we are more likely to observe co-promotion arrangements, I examine the pattern of arrangements in the biopharmaceutical industry.\(^4\)

#### 4.1 The biopharmaceutical industry

The biopharmaceutical industry can be traced to the founding of Genentech in 1976 to exploit the recombinant DNA techniques discovered by Herbert Boyer at the University of California at San Francisco and Stanley Cohen at Stanford in 1972. From the beginning, entering alliance with a pharmaceutical firm has been the predominant mode by which biotech innovations were commercialized. Genentech’s first major project – a race with UCSF and Harvard University to clone human insulin, the key protein diabetics need to normalize their metabolism – resulted in an alliance with Lilly to commercialize the discovery (“Humulin”) as a pharmaceutical product (Edwards & Hamilton, 1998).

The Genentech/Lilly alliance set the standard for interaction between the new “biotech” firms and the established pharmaceutical firms. The biotech firm licensed all product rights to an established

\[^4\] The biopharmaceutical or medical “biotech” industry is distinct from the agricultural and industrial “biotech” industries.
pharmaceutical firm, and remained involved through the pre-clinical stages of development, but then passed all responsibility for the clinical development, marketing, and worldwide sales to the pharmaceutical firm. However, the structure of these commercialization arrangements has changed significantly over time, as biotech firms have increasingly sought to become more involved in the commercialization process.\(^5\) As a first step, biotech firms began to participate in the clinical development stages of the alliance, both participating in management of the clinical trials and sharing the costs (and thereby also the profit or loss) from clinical development, an arrangement known as “co-development”. More recently biotech firms have integrated even further downstream inside the alliance, retaining rights to participate in the marketing and sales of the alliance product, known as “co-promotion”.\(^6\) Under a co-promotion arrangement the biotech firm licenses the marketing rights to the pharmaceutical partner, but retains some rights to participate in the marketing and sales process alongside the partner. The two parties together develop a joint marketing strategy and sales force, sell under the same brand name, and pool – and ultimately split – revenues.\(^7\)

\(^5\) It was not uncommon in the early alliances for the biotech firm to retain rights to some territories (especially its home country) or, in a few cases, rights to specific indications. For instance, at the same time as Genentech entered the Lilly alliance, it also signed a deal with Kabi Pharmaceutical to commercialize human growth hormone but retained the rights to commercialize the product in the United States. Meanwhile, Amgen retained rights to sell to kidney dialysis patients in its alliance with Ortho Biotech to commercialize EPO.

\(^6\) A well-known example is ImClone’s 2001 arrangement with Bristol-Myers Squibb to commercialize its cancer drug Erbitux. Another is the deal between Idec Pharmaceuticals (now part of Biogen Idec) and Genentech in 1996 for the commercialization of Rituxan, a drug for non-Hodgkin’s lymphoma, which has since become the largest selling monoclonal antibody drug and a significant contributor to the profits of both companies.

\(^7\) Co-promotion can be contrasted against several other arrangements for commercializing biotech innovations. The most obvious contrast is the pure product license in which the biotech firm licenses all marketing & distribution rights to the pharmaceutical firm. However, one alternative which involves a greater degree of participation by the biotech firm is split territories (or, in a few cases, indications) under which the firms develop, market, and sell the same drug in separate (exclusive) territories. A third, if rare, alternative is co-marketing in which the firms develop, market, and sell the drug in same territory but with different marketing strategies, sales forces, and brand names.
4.2 Evidence from interviews

In order to understand the motivation for entering co-promotion arrangements, I conducted a series of interviews with biotech firm executives. From the list of executives who attended Recombinant Capital’s Allicense conference in San Francisco on May 2-3, 2006, I selected executives from “start up” biotech firms whose firms either had retained co-promotion rights in recent agreements with established pharmaceutical firms or fully integrated biotech firms or had recently entered licensing agreements without retaining co-promotion rights. I invited them to speak with me, either generally about why start-up biotech firms retain co-promotion rights in alliances or specifically about the reasons their company chose to retain (or not to retain) co-promotion rights in its recent agreements. I conducted phone interviews with ten executives during late May/early June 2006.

The primary reason the executives cited for retaining co-promotion rights was the belief that the biotech firm would capture a larger share of the value from its technology by being involved in the marketing of the alliance product than if it merely licenses the marketing rights to a pharmaceutical firm. Many echoed the refrain that “Wall Street values ‘decision rights’ over ‘revenue rights’.” They argued that companies which had only done licensing deals had not been very successful. Some claimed that the revenue the firm earned from the profit split (typically between 33% and 50%) that usually accompanies a co-promotion agreement was usually greater than it earns from the combination of upfront payments and royalties (typically in the range of 10% of net sales) that a firm

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8 *Allicense* is the primary industry conference focusing on alliances between biotech and pharmaceutical firms, and is attended by the senior business development executives from all the major pharmaceutical and mature biotech firms, as well as CEOs and other senior executives from many start-up biotech firms.

9 I distinguish between fully integrated biotech firms that already have pharmaceutical products on the market, and “start-up” biotech firms, which do not have products on the market and do not yet have the capabilities to commercialize product candidates alone.

10 I only considered firms that I estimated were likely to have been in a position to retain such rights. I estimated the likelihood that the firm would have retained co-promotion rights through an informal inspection of their prior licensing experience, financial strength, and various other observable factors in Recap’s Alliances database.

11 This claim was made by Stephen R. Davis, Executive Vice President and Chief Operating Officer, Neurogen, at the *Allicense* conference in San Francisco on May 25, 2005.
can get from an equivalent pure-licensing deal. However, others argued that, even though a pure-licensing agreement could be structured to produce as much income as a co-promotion agreement, a co-promotion arrangement gave the biotech firm greater insight into the business of commercializing pharmaceutical products and therefore was more valuable.

The executives claimed that the primary benefit from entering co-promotion arrangements is that the biotech firm acquires valuable knowledge by participating in the commercialization process alongside the pharmaceutical firm. One executive explained that by retaining co-promotion rights the biotech firm is able to “piggy back” on the expertise of its alliance partner to build its own capabilities. Another stated that the way to “score big” was to “leverage the alliance partner’s expertise internally” to learn the skills necessary to develop the next drug.

A secondary benefit of retaining co-promotion rights is that the firm retains some control over the development and marketing process. Since neither firm knows at the outset the size of the potential market for the alliance product, a biotech firm’s concern is that – if the potential market for the product turns out not to be sufficiently large – its alliance partner will not put in the resources necessary to commercialize it. Hence, it is important to have a voice at the table to make sure the drug gets developed on the biotech firm’s timeframe. One executive claimed that retaining some rights to participate in the marketing enables the firm to be “the nag that makes sure the drug gets developed”. Others explained that, while the deal could include “due diligence” or “best efforts” requirements, a lot of pharmaceutical firms would not agree to them because it was hard to define “best (or reasonable) efforts” and, if they did agree to such a clause, they were usually very vague and legally meaningless.

Some executives claimed that they would always retain co-promotion rights if they could, but others identified cases in which they would not seek co-promotion rights. If the firm needed cash, so was forced to enter an alliance at an early stage in the product’s development, then retaining co-promotion rights was not usually worth the cost (in terms of money foregone). One executive quipped that the “first child” of the biotech firm typically had to be sold (i.e., licensed exclusively) to a pharmaceutical firm in order to fund the development of future products. Also, if the disease field on which the alliance product is focused was outside the firm’s “strategic interests”, or was in a very competitive field, then the biotech is likely to give up rights to the product.

The executives also explained why they believed pharmaceutical firms were willing to give up marketing rights, even though marketing is their specialty. They claimed that pharmaceutical firms often did not have the leverage (especially in negotiations over very promising technologies) to negotiate all the rights to market the product, and hence they were forced to agree to co-promotion in order to secure the biotech firm’s agreement. Nevertheless, the pharmaceutical firm may seek to buy
those rights back – or even purchase the technology firm outright – if and when the product gets to market. Moreover, some companies had a policy of never agreeing to co-promote, especially when the biotech firm did not have the necessary experience.

4.3 Data

In order to test the predictions outlined in the previous section, I compiled a unique dataset of technology commercialization arrangements used by U.S. biotech firms attempting to commercialize products in the pharmaceutical industry. The dataset contains information on 1590 instances in which a biotech firm held exclusive rights to market a specific indication of a biopharmaceutical product in the United States for some period of time while the product was in clinical trials between 1978 and 2008. In 342 of the 1590 instances, the biotech firm’s product rights ended when it entered a technology commercialization arrangement with a pharmaceutical firm. However, since often one alliance involves more than one product-indication this corresponds to 164 unique alliances.

The data comes from RecapRx, a proprietary database compiled by Deloitte Recap (“Recap”). RecapRx links the alliance data to specific biotech products, and provides detail on the clinical development of each indication for the product. Using the data on RecapRx, I manually selected those alliances that involved a biotech firm transferring the rights to market the product in the United States. I then used Recap’s Alliances database (called “rDNA”) to obtain additional data on the terms of those alliances. I further supplemented this information with details on the biotech firm’s valuation. I used the CRSP database to obtain the market capitalization for those biotech firms that were publicly

12 Amgen’s alliance with Abgenix is an example of this happening. In July 2000 Abgenix entered a deal with Immunex to co-promote Abgenix’s product panitumumab, a drug for late-stage colorectal cancer therapies that was then in Phase I trials. However, after Amgen acquired Immunex and the product passed through Phase III trials, Amgen purchased Abgenix outright. One rationale for doing so is that Amgen thereby avoided having to share the marketing with a smaller firm.

13 Of the 1248 other instances, in 231 the biotech firm’s product rights ended when it was acquired during clinical trials, 15 when the rights reverted to an earlier licensor, and 323 because the product development was terminated. In the remainder, the biotech firm still had the rights when it exited the analysis, either because the product was approved or the observation period ended (i.e., in December 2008).
listed and Recap’s Financings dataset available within rDNA to obtain information about the private financing events where it was available.  

What is unique about this dataset – and what distinguishes it from the numerous datasets used in previous research on alliances, many of which were based on Recap’s rDNA database – is that all the alliances involve the transfer of U.S. marketing rights to identifiable biopharmaceutical products. By contrast, the alliances included in most previous analyses that use biotech alliance data include both technology- and product-related alliances. Mixing different types of alliances in the same analysis makes it much more difficult to determine what is causing the observed patterns. In this case, we can be much more confident that the parties to the alliances were negotiating over similar issues and therefore the observed patterns can be attributed to the same determinants.

4.4 Empirical specification

The objective of the empirical analysis is to estimate a model that accounts for the biotech firm’s choice of technology commercialization strategy:

$$\operatorname{Pr}(CS | X) = f(X, \beta)$$  \hspace{1cm} (21)

where $CS$ represents the biotech’s commercialization strategy and $X$ is a vector of explanatory variables.

However, in practice we observe the biotech firm’s choice of commercialization strategy in two stages: first we observe whether the biotech firm decides whether or not to license at a particular point in time; and second we observe the type of alliance it negotiates. Nevertheless, as the model highlights, similar factors which determine whether the biotech firm enters an alliance to commercialize its product also influence the structure of the agreement. Therefore, following Heckman (1979), I estimate a two-stage model of the biotech firm’s technology commercialization strategy. The first-stage selection equation estimates the likelihood that the biotech firm enters into a commercialization alliance in any given month that it has the U.S. marketing rights, and the second stage equation estimates the likelihood that the firms negotiate a co-promotion arrangement or a  

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14 Recap compiles its Financings dataset from publicly filed documents, so in general it includes information on firms that made an Initial Public Offering or otherwise were required to disclose this information. However, in contrast to Venture Xpert and other similar sources that collect information from voluntary surveys, Recap’s information comes from legally mandated filings and therefore should be more accurate.
straight licensing arrangement (conditional on having entered a deal). The first-stage, selection equation is:

$$\Pr( CS \in \{L, CP\} \mid Z) = \Phi(Z\gamma)$$

(22)

where $L$ is an indicator of whether $T$ entered into a straight licensing arrangement, $CP$ is an indicator of whether $T$ entered into a co-promotion arrangement, $Z$ is a vector of explanatory variables, $\gamma$ is a vector of unknown parameters, and $\Phi$ is the cumulative distribution function of the standard normal distribution.

The second-stage equation is

$$\Pr( CS = CP \mid CS \in \{L, CP\}, X) = X\beta + \rho\sigma_u\lambda(Z\gamma)$$

(23)

where $\rho$ is the correlation between unobserved determinants of propensity to contract $\varepsilon$ and unobserved determinants of choosing co-promotion $u$, $\sigma_u$ is the standard deviation of $u$, and $\lambda$ is the inverse Mills ratio evaluated at $Z\gamma$.

### 4.5 Variables

The dependent variable for the first-stage of the Heckman analysis is an indicator of whether the biotech firm licensed out the rights to commercialize its product in the U.S. in a given period. This is coded 1 if there is a licensing agreement in that period and zero otherwise. The dependent variable for the second-stage analysis is an indicator of whether the biotech firm retained co-promotion rights in the agreement ($CP=1$). For this variable I rely on Recap’s coding of the alliance contract terms provided in the Alliance Summary on rDNA. Recap defines a “Co-Promotion” agreement as “a commercialization venture in which two or more parties promote and sell a single product, with each party obtaining sales revenues and/or net profits from either party’s sales of the product”. I classify any other arrangement that involves the transfer of U.S. marketing rights as a straight licensing arrangement.

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15 Recap codes this information whenever it is observed in the public announcement or the filed contract(s). They advise that this information is almost always revealed in the public announcement because of the belief that it will be rewarded by the financial markets.
It is important to note that the commercialization strategy analyzed here reflects the action taken in a particular month, rather than the commercialization strategy that the biotech firm ultimately pursues or the strategy that the firm intends to put into action in the future. Even if I observe a firm not licensing out the commercialization rights in a particular month, it may still intend to – and may in fact – enter an alliance at a later point in time. Moreover, even if I observe a firm entering a co-promotion arrangement in a particular month, it may subsequently negotiate the agreement to re-obtain the full commercialization rights or alternatively to license out the rights completely.

The primary explanatory variables proxy for the parameters in the model. To proxy for the number of product firms competing to license the innovation, I count the number of product firms that were the licensee on any alliance in the same disease field in the 2 years before and one year after the alliance was signed. The reason for including alliances signed within a year after the alliance is that an alliance usually takes 6-18 months to negotiate and during the negotiations the technology firm usually has some information on what other alternatives its potential partner is considering. Since I expect that the relationship between the number of product firms and the likelihood of retaining co-promotion rights is concave, I use the log value.

I proxy for the probability that the biotech firm will innovate in the particular product field in subsequent periods ($\phi$) using the proportion of biotech firm's prior alliances that were in the same disease field, as coded by Recap. According to the resource-based theory of the firm (Penrose, 1959; Wernerfelt, 1984), a firm’s ability to generate outputs is constrained by its existing set of resources and capabilities, so we can reasonably assume that a technology firm is likely to produce future

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16 I include all alliances where the “Client” (as per Recap’s classification) was “Pharma” firm, or a “Biotech” firm that had a product on the market at the time of the deal.

17 This variable is an approximate measure of the potential licensees. An alternative measure of the number of firms competing to license the innovation would be a count of those firms that were actually marketing products in the specific disease field. This would be more direct evidence that it has the specific commercialization capabilities in the disease field. However, it would not account for pharmaceutical firms that had products in the pipeline that would be on the market in the coming years.

18 I use the Recap’s 23 broad disease categories, which includes Cancer, Cardiovascular, etc.
innovations in the same fields in which has done so previously. Hence the focus of the firm’s prior activity ought to be a good predictor of the focus of its future activity.19

I measure the biotech firm’s financial strength using an estimate of the firm’s valuation, normalized to December 2008 dollars. For the publicly listed firms I use the market capitalization at the end of the previous month, obtained from CRSP.20 For the privately held firms, I use the valuation at the last private financing round (whenever it is available) obtained from the rDNA Financing database. Since I expect that the likelihood of entering into a deal or retaining co-promotion rights will more closely related to a proportional increase in the valuation than an absolute increase, I use the log value.

Since $\phi$ and $N$ are measured for a specific disease field, the relevant comparison is to other observations in the same disease field and hence I include disease-field fixed effects.

To identify the second equation in a Heckman selection model, it is necessary to exclude at least one variable that appears with a non-zero coefficient in the first-stage (selection) equation from the second-stage equation (i.e., to impose an exclusion restriction). There is anecdotal evidence that firms are under pressure to sign deals towards the end of the quarter or year so that they can be included in the quarterly and annual filings, and large firms regularly set quarterly and annual targets for the number of deals that their business development departments should achieve. However, even if they firms can manipulate the date on which they sign and announce a deal, it typically takes from 6 to 18 months to negotiate the terms of the deal, and the general terms are typically negotiated and specified in a term sheet months beforehand. Hence the particular month in which the firms sign the alliance should not directly affect whether the firms negotiate a co-promotion or a straight licensing arrangement. I include an indicator for whether the deal was signed in the last month of the quarter or the last month of the year as an instrumental variable in the first-stage Heckman selection regression.

To control for the biotech firm’s prior experience, I include the firm’s age in months since founding and the log value of the count of prior alliances. I also include indicators for whether the biotech has

19 An alternative measure of the probability that the firm will innovate in the product field would be some measure of the firm’s R&D capabilities in particular product. One such measure might be its stock of patents. However, since patents protect an underlying technology rather than a specific product, it is difficult if not impossible to relate a firm’s patent stock to particular product fields.

20 The information on firm valuation is only available when disclosed in SEC filings, either because the firm was publicly listed or because this information was included in its IPO filing when it later went public.
marketing rights to another product in the same or another disease field, dummies to represent the stage of clinical development of the product candidate in the particular month, and an index of the biotech equity market conditions. Finally, I include dummies the representing 5-year time periods (1975-79, 1980-84, etc.) to capture any time trend in the dependent variable.

Table 1 presents summary statistics for the values of the key variables if product rights were transferred in the particular month. It shows, in particular, that the biotech firm retained rights to co-promote the alliance product in 43% of the alliances.

**Table 1: Summary statistics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean</th>
<th>s.d.</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotech retains rights to co-promote the alliance product</td>
<td>0.43</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of product firms active in disease field</td>
<td>125.50</td>
<td>67.06</td>
<td>1.00</td>
<td>218.00</td>
</tr>
<tr>
<td>Proportion of biotech firm’s prior alliances in disease field</td>
<td>0.27</td>
<td>0.26</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Valuation ($M)</td>
<td>4824.02</td>
<td>16639.23</td>
<td>-49.88896</td>
<td>100011.40</td>
</tr>
<tr>
<td>Age (months since founding)</td>
<td>172.00</td>
<td>76.91</td>
<td>4</td>
<td>489</td>
</tr>
<tr>
<td>Count of biotech’s prior alliances</td>
<td>47.74</td>
<td>55.49</td>
<td>1</td>
<td>309</td>
</tr>
<tr>
<td>Biotech already has marketing rights to approved product in same disease field (d)</td>
<td>0.19</td>
<td>0.40</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Biotech already has marketing rights to approved product in another disease field (d)</td>
<td>0.18</td>
<td>0.38</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Product passed Phase I (d)</td>
<td>0.62</td>
<td>0.49</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Product passed Phase II (d)</td>
<td>0.33</td>
<td>0.47</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Biotech equity market index</td>
<td>548.35</td>
<td>295.88</td>
<td>93.37</td>
<td>1022.82</td>
</tr>
<tr>
<td>Year of alliance</td>
<td>2001.35</td>
<td>5.06</td>
<td>1985</td>
<td>2008</td>
</tr>
</tbody>
</table>

Notes:
1. All pharmaceutical firms or biotech firms with marketing rights to an approved product that have a transaction in product field in two years prior or year following the alliance.
3. For publicly listed firms, market valuation at end of prior month; for private firms, post-money value at end of last financing round.

Table 2 shows the correlations between the variables used in the analysis. There is a high correlation between the number of product firms active in disease field and the year of the alliance, which is helpful in interpreting the effect of the explanatory variable when time dummies are included in the analysis (see below). Otherwise the correlations with the key explanatory variables and the other do not create any cause for concern.

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21 Josh Lerner generously provided an index of biotech equity stocks from 1978-1997. I use the Amex index (which starts in 1994) for the years 1998-2008. Both indexes are normalized to 100 at 12/31/1997. The correlation between these two indexes for the years they run in parallel is 1.0000.
Table 2: Correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0) Biotech retains rights to co-promote the alliance product</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Number of product firms active in disease field(d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.14</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Proportion of biotech firm's prior alliances in disease field</td>
<td></td>
<td></td>
<td></td>
<td>0.19</td>
<td>0.31</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Valuation ($M)^{23}</td>
<td>-0.09</td>
<td>-0.05</td>
<td>-0.14</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Age (months since founding)</td>
<td>-0.16</td>
<td>0.24</td>
<td>-0.21</td>
<td>0.41</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Count of biotech’s prior alliances</td>
<td>-0.14</td>
<td>0.10</td>
<td>-0.28</td>
<td>0.71</td>
<td>0.58</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Biotech already has marketing rights to approved product in same disease field (d)</td>
<td>-0.20</td>
<td>0.17</td>
<td>0.05</td>
<td>0.34</td>
<td>0.31</td>
<td>0.39</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) Biotech already has marketing rights to approved product in another disease field (d)</td>
<td>-0.09</td>
<td>-0.09</td>
<td>-0.28</td>
<td>0.07</td>
<td>0.26</td>
<td>0.15</td>
<td>-0.23</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) Product passed Phase I (d)</td>
<td>-0.05</td>
<td>0.18</td>
<td>0.16</td>
<td>0.08</td>
<td>0.24</td>
<td>0.14</td>
<td>0.26</td>
<td>-0.11</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) Product passed Phase II (d)</td>
<td>-0.16</td>
<td>-0.05</td>
<td>0.07</td>
<td>0.10</td>
<td>0.15</td>
<td>0.06</td>
<td>0.31</td>
<td>-0.08</td>
<td>0.55</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10) Biotech equity market index</td>
<td>0.08</td>
<td>0.57</td>
<td>0.04</td>
<td>0.12</td>
<td>0.47</td>
<td>0.26</td>
<td>0.20</td>
<td>-0.01</td>
<td>0.24</td>
<td>0.04</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>(11) Year of alliance</td>
<td>0.12</td>
<td>0.61</td>
<td>0.09</td>
<td>0.09</td>
<td>0.46</td>
<td>0.27</td>
<td>0.23</td>
<td>-0.06</td>
<td>0.34</td>
<td>0.09</td>
<td>0.88</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Notes:
1. All pharmaceutical firms or biotech firms with marketing rights to an approved product that have a transaction in product field in two years prior or year following the alliance.
3. For publicly listed firms, market valuation at end of prior month; for private firms, post-money value at end of last financing round.
4.6 Results

Table 3 presents the results of the analysis of whether the biotech firm outlicenses the U.S. product rights in any given month. Model 1 is a probit analysis of the monthly observations. Model 2 is Cox proportional hazard-rate analysis of entering a deal in any specific month. Model 3 is a multinomial logit regression that estimates the relationship between three alternative choices of commercialization modes simultaneously. The first column contains the effects on outlicensing but retaining co-promotion rights and the second column contains the effects on outlicensing all commercialization rights, both relative to the (omitted) outcome that the biotech firm does not license out the commercialization rights. The standard errors are clustered by firm-product-indication.

Table 3: Analysis of biotech commercialization strategy (as against not licensing)

<table>
<thead>
<tr>
<th>Empirical specification</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probit</td>
<td>Cox prop. hazard rate</td>
<td>Multinomial logit</td>
</tr>
<tr>
<td>Dependent variable</td>
<td>Biotech outlicenses commercializaton rights</td>
<td>Biotech outlicenses commercializaton rights</td>
<td>Biotech outlicenses ALL commercializaton rights</td>
</tr>
<tr>
<td>1. Number of product firms active in disease field (log)</td>
<td>0.0209 (0.0725)</td>
<td>0.593 (0.469)</td>
<td>-0.294 (0.224)</td>
</tr>
<tr>
<td>2. Proportion of biotech firm's prior alliances in disease field</td>
<td>-0.200 (0.0960)**</td>
<td>-0.567 (0.273)**</td>
<td>-1.192 (0.387)***</td>
</tr>
<tr>
<td>3. Valuation ($M, log)</td>
<td>-0.0520 (0.0143)***</td>
<td>-0.134 (0.0403)***</td>
<td>-0.220 (0.0475)***</td>
</tr>
<tr>
<td>4. Age</td>
<td>-0.00133 (0.000330)***</td>
<td>-0.00372 (0.000976)***</td>
<td>-0.00300 (0.00125)**</td>
</tr>
<tr>
<td>5. Count of biotech’s prior alliances (log)</td>
<td>-0.0147 (0.0302)</td>
<td>-0.0539 (0.0855)</td>
<td>0.00001385 (0.114)</td>
</tr>
<tr>
<td>6. Biotech already has marketing rights to approved product in same disease field (d)</td>
<td>-0.157 (0.0596)***</td>
<td>-0.498 (0.182)**</td>
<td>0.0262 (0.225)</td>
</tr>
<tr>
<td>7. Biotech already has marketing rights to approved product in another disease field (d)</td>
<td>0.123 (0.0616)***</td>
<td>0.353 (0.179)**</td>
<td>0.693 (0.231)***</td>
</tr>
<tr>
<td>8. Product has entered Phase II trials (d)</td>
<td>0.0173 (0.0471)</td>
<td>0.0587 (0.136)</td>
<td>0.0172 (0.190)</td>
</tr>
<tr>
<td>9. Product has entered Phase III trials (d)</td>
<td>0.124 (0.0518)**</td>
<td>0.388 (0.147)***</td>
<td>0.486 (0.206)**</td>
</tr>
<tr>
<td>10. Biotech equity market index</td>
<td>0.0000912 (0.0000889)</td>
<td>0.000292 (0.000326)</td>
<td>-0.000130 (0.000399)</td>
</tr>
<tr>
<td>11. Last month of quarter or last quarter of year (d)</td>
<td>0.0927 (0.0376)**</td>
<td>0.0263 (0.143)</td>
<td>0.598 (0.174)***</td>
</tr>
<tr>
<td>12. Constant</td>
<td>-1.809 (0.386)***</td>
<td>-1.667 (1.198)</td>
<td>9.454 (2.001)***</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses, clustered by firm-product-indication; *** p<0.01, ** p<0.05, * p<0.1
Notes:
1. All pharmaceutical firms or biotech firms with marketing rights to an approved product that have a transaction in product field in two years prior or year following the alliance.
3. For publicly listed firms, market valuation at end of prior month; for private firms, post-money value at end of last financing round.

Table 4 presents the results of a series of OLS regressions of whether the biotech firm retains co-promotion rights when it enters into a commercialization deal. Models 1 to 3 include the inverse Mills ratio, calculated from the results of Model 1 in Table 3 to adjust for selection into doing a deal. Model 1 contains just the 3 key explanatory variables with disease-field fixed effects. Model 2 includes the control variables, and Model 3 includes the time-period fixed effects. For comparison, Model 4 is an OLS regression without the inverse Mills ratio (i.e., without adjusting for selection). Since multiple product-indications may be transferred in once alliance, the standard errors for the regressions presented in Table 4 are clustered for the same alliance.

Table 4: Analysis of biotech commercialization strategy (as against entering straight licensing arrangement)

<table>
<thead>
<tr>
<th>Empirical specification</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable:</td>
<td>Biotech retains co-promotion rights</td>
<td>Biotech retains co-promotion rights</td>
<td>Biotech retains co-promotion rights</td>
<td>Biotech retains co-promotion rights</td>
</tr>
<tr>
<td>1. Number of product firms active in disease field (log)</td>
<td>0.278 (0.102)***</td>
<td>0.428 (0.126)***</td>
<td>0.0330 (0.372)</td>
<td>0.428 (0.126)***</td>
</tr>
<tr>
<td>2. Proportion of biotech firm's prior alliances in disease field</td>
<td>0.481</td>
<td>0.672</td>
<td>0.173</td>
<td>0.672</td>
</tr>
<tr>
<td>3. Valuation ($M, log)</td>
<td>0.0501 (0.0406)</td>
<td>0.157 (0.0537)**</td>
<td>0.154 (0.0580)**</td>
<td>0.157 (0.0537)**</td>
</tr>
<tr>
<td>4. Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Count of biotech’s prior alliances (log)</td>
<td>0.0141 (0.00112)</td>
<td>0.0259 (0.00136)</td>
<td>0.0259 (0.00136)</td>
<td>0.0259 (0.00136)</td>
</tr>
<tr>
<td>6. Biotech already has marketing rights to approved product in same disease field (d)</td>
<td>0.0254</td>
<td>0.0814</td>
<td>0.0254</td>
<td>0.0254</td>
</tr>
<tr>
<td>7. Biotech already has marketing rights to approved product in another disease field (d)</td>
<td>-0.415</td>
<td>-0.432</td>
<td>-0.415</td>
<td>-0.415</td>
</tr>
<tr>
<td>8. Product has entered Phase II trials (d)</td>
<td>-0.0646</td>
<td>-0.0525</td>
<td>-0.0646</td>
<td>-0.0646</td>
</tr>
<tr>
<td>9. Product has entered Phase III trials (d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Biotech equity market index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Inverse Mills ratio</td>
<td>-0.953 (0.340)***</td>
<td>-2.179 (1.013)***</td>
<td>-2.179 (1.025)**</td>
<td>-2.179 (1.013)***</td>
</tr>
<tr>
<td>Constant</td>
<td>1.638</td>
<td>4.167</td>
<td>6.285</td>
<td>4.167</td>
</tr>
<tr>
<td>Disease field fixed effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Time-period dummies</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Number of firm-product-indications</td>
<td>342</td>
<td>342</td>
<td>342</td>
<td>342</td>
</tr>
<tr>
<td>Number of unique alliances</td>
<td>164</td>
<td>164</td>
<td>164</td>
<td>164</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.115</td>
<td>0.199</td>
<td>0.203</td>
<td>0.199</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses, clustered by alliance; *** p<0.01, ** p<0.05, * p<0.1
Notes:
1. All pharmaceutical firms or biotech firms with marketing rights to an approved product that have a transaction in product field in two years prior or year following the alliance.
3. For publicly listed firms, market valuation at end of prior month; for private firms, post-money value at end of last financing round.

4.7 Discussion

The results of the empirical analysis are generally consistent with the predictions from the model. Proposition 1(a) posits that a technology firm will be more likely to retain the rights to its product (i.e., not enter into a commercialization deal with a product firm), the higher the probability that it will generate an innovation related to that product field in future. The results in Table 3 show that a biotech firm is less likely to outlicense its product when it has more activity in the same disease field in the prior licensing arrangements, which is a proxy for the likelihood that it will generate an innovation in that field in future. These results are robust to the econometric specification of the regression.

Proposition 2 posits that a firm will be more likely to retain co-promotion rights if there is a higher probability that it will generate an innovation related to that product field in future. The three models in Table 4 all show a strong positive correlation between the proportion of prior alliances in the same field and whether the biotech retains co-promotion rights under all three specifications. Moreover, the results of Model 3 in Table 3 show that when a biotech firm has a higher proportion of prior alliances in the same field, it is significantly less likely to enter into a pure licensing arrangement relative to entering a co-promotion arrangement or not licensing at all. Both findings are consistent with the prediction in Proposition 2.

However, the empirical analysis does not provide evidence for Proposition 1(c) – that a technology firm will be more likely to retain the rights to its product with the more potential licensees. Nevertheless, they do provide some evidence that technology firms are more likely to enter a co-promotion arrangement rather than a straight licensing arrangement when there are more potential licensees. Models 1 and 2 in Table 4 show a positive correlation between retaining co-promotion rights and the number of product firms active in the disease field.22 Moreover, the results of Model 3

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22 The coefficient on the explanatory variable in Model 3 of Table 4 is not statistically significant, suggesting this effect is not robust to the specification. However, we know from Table 2 that the number of product firms
in Table 3 show that when there are more product firms active in the disease field, a biotech firm is significantly more likely to enter into a co-promotion arrangement but no more likely to enter into a pure licensing arrangement (as against not licensing the innovation).

Taken together, the results provide support for the argument that a biotech firm enters into a co-promotion arrangement in order to build specialized commercialization capabilities in the disease field of the alliance. The results show that a firm is more likely to enter into a co-promotion arrangement or not license at all when its R&D activities are more focused on the particular disease field to which the alliance relates. If it already has marketing rights to an approved product in that field, it either enters a co-promotion arrangement or does not license at all. However, if the biotech firm already has rights to an approved product in another disease field, then it is unlikely to retain co-promotion rights. Since commercialization capabilities are specific to a disease field, and are costly to develop and maintain, the biotech firm appears to prefer licensing out the rights to such products so it can focus its resources on maintaining its commercialization capabilities in specific fields.

5. Conclusion

This paper formalizes, extends, and tests the framework for analyzing technology commercialization strategy presented in Teece (1986). It places the one-off decision imagines in Teece (1986) in a multi-period framework in which the innovating firm has the opportunity to learn from its own experience in commercialization. The paper shows that, when the innovating firm has specialized technological capabilities and the opportunity to acquire its own commercialization capabilities through experiential learning, it may be optimal to commercialize its innovation under certain conditions. Moreover, a hybrid strategy – in which the technology firm contracts with a product firm but retains the rights to participate in the commercialization process – may enable the technology firm to capture an even greater share of the profits over the long term.

The technology firm prefers this arrangement because it reduces the risk of failure in the short term, enabling it to bring its latest innovation to market in a timely and cost-effective manner, and enables it to acquire the knowledge necessary to commercialize future innovations alone over the long term. Nevertheless, to do so it must compensate the product firm for training it to become a competitor, something the product firm will only agree to if it is competing with other product firms to license the innovation. Moreover, the technology firm is only better off pursuing this strategy if it is likely to

that are active in a field has increased dramatically over all fields over time (i.e., is strongly correlated with the year of observation), which may affect the ability to estimate the effect of the explanatory variable precisely.
generate sufficient innovations in the same product field in future, and it is in a strong enough financial position to forego the higher upfront revenues that a pure licensing arrangement would generate.

The paper has some pertinent implications for managers. While it may be necessary for a technology firm to partner with an established firm to obtain access to the requisite complementary assets, in negotiating such an alliance managers must also consider how the firm can achieve superior profitability over the long term. If the firm has specialized technological capabilities, so it expects to generate future innovations in the same product field, it is important to loosen the control that the established firms over the complementary assets necessary to commercialize an innovation. One way to do this is to use its leverage in alliance negotiations to acquire the knowledge necessary to build its own commercialization capabilities. Specifically, it can negotiate to the rights to participate in the commercialization process, and thereby learn directly from its alliance partner.

However, acquiring commercialization capabilities will only be worthwhile if the firm can generate sufficient innovations in the same product field. Building its own commercialization capabilities requires a substantial investment, which will only give a return over the longer term. At the same time, retaining rights to participate in the commercialization process is likely to involve sacrificing greater financial payments. While maintaining control over the commercialization process and acquiring its own capabilities may give the firm access to a greater revenue stream in the long term, negotiating greater financial payments helps it to meet short-term obligations. If the firm is financially constrained, it may be better off giving up control of its innovations until it is in a stronger position. If the innovation is outside the firm’s core focus then it is likely to be better off licensing the innovation and remaining out of the product field.
Appendix: Proofs from Section 3

Proof of Lemma 1

From (8) above, licensing will be a equilibrium in the game without experiential learning if

\[ c_i \leq 2\lambda_1(1)\pi - \lambda_{NL}^P(1)\pi - \lambda_{NL}^T(1)\pi \]

Substituting in the values of \( \lambda_1(1) \), \( \lambda_{NL}^P(1) \), and \( \lambda_{NL}^T(1) \) into this expressions gives

\[ c_i \leq \left(1 - \sigma_{NL}^P\right)\left(\sigma_{NL}^T - \sigma_{NL}^T\right)\pi \]

By definition, \( 0 \leq \sigma_{NL}^P < 1 \) and \( \pi > 0 \), so \( \left(1 - \sigma_{NL}^P\right)\left(\sigma_{NL}^T - \sigma_{NL}^T\right)\pi > 0 \) and for all allowable values of \( \sigma_{NL}^P \) and \( \sigma_{NL}^T \) there are non-negative values of \( c_i \) that satisfy this equation. Moreover, if \( c_i = 0 \) then the licensing will be the unique equilibrium for all allowable values of \( \sigma_{NL}^P \) and \( \sigma_{NL}^T \).

Proof of Lemma 2

From (9) above, the parties will agree to licensing in the game with experiential learning if

\[ c_i \leq \frac{1 - \delta}{1 - \delta(1 - \sigma_{NL}^T)} \left[2\lambda_1(1)\pi - \lambda_{NL}^P(1)\pi - \lambda_{NL}^T(1)\pi\right] \]

Substituting the values of \( \lambda_1(1) \), \( \lambda_{NL}^P(1) \), and \( \lambda_{NL}^T(1) \) into these expressions gives

\[ c_i \leq \frac{1 - \delta}{1 - \delta(1 - \sigma_{NL}^P)} \left(1 - \sigma_{NL}^P\right)\left(\sigma_{NL}^T - \sigma_{NL}^T\right)\pi \]

Since \( 0 \leq \sigma_{NL}^P < 1 \) by definition, \( \frac{1 - \delta}{1 - \delta(1 - \sigma_{NL}^T)} < 1 \) and therefore

\[ \frac{1 - \delta}{1 - \delta(1 - \sigma_{NL}^P)} \left(1 - \sigma_{NL}^P\right)\left(\sigma_{NL}^T - \sigma_{NL}^T\right)\pi \leq c_i \leq \left(1 - \sigma_{NL}^P\right)\left(\sigma_{NL}^T - \sigma_{NL}^T\right)\pi \]

Hence the likelihood that licensing is an equilibrium outcome is lower in a technology commercialization game with experiential learning than without, or conversely the likelihood that not
licensing is an equilibrium outcome is higher in a technology commercialization game with experiential learning than without.

**Proof of Proposition 1**

(a) From (16), in the game with experiential learning where \( \phi \leq 1 \) the parties will choose licensing over letting \( T \) commercialize alone if

\[
c_t \leq \frac{1 - \delta}{1 - \delta \phi \sigma^\text{NL}_T} \left( 2\lambda_{11}(1)\pi - \lambda^\text{NL}_{Tc}(1)\pi - \lambda^\text{NL}_{Ni}(1)\pi \right)
\]

The derivative of the right hand side with respect to \( \phi \) is

\[
\frac{\partial}{\partial \phi} \left( \frac{1 - \delta}{1 - \delta \phi \sigma^\text{NL}_T} \left( 2\lambda_{11}(1)\pi - \lambda^\text{NL}_{Tc}(1)\pi - \lambda^\text{NL}_{Ni}(1)\pi \right) \right)
\]

Since \( 0 < \sigma^\text{NL}_T < 1 \) and \( 0 < \phi < 1 \) by definition, the derivative with respect to \( \phi \) is always negative and hence the right-hand side of (16) is decreasing in \( \phi \). This means that as \( \phi \) increases, there will be fewer values of \( c_t \) for which licensing is an equilibrium and hence the likelihood that licensing in an equilibrium decreases, all else held equal.

(b) From (19), in the game with experiential learning and \( N > 1 \) licensing will be an equilibrium if

\[
c_t \leq \frac{1 - \delta}{1 - \delta \phi \sigma^\text{NL}_T} \left( \lambda_{11}(N)\pi - \lambda^\text{NL}_{Tc}(N)\pi + \frac{N}{N - \delta(N - 1)} \left( \lambda_{11}(N)\pi - \lambda^\text{NL}_{Ni}(N)\pi \right) \right)
\]

Since the expansions of \( \lambda_{11}(N) \), \( \lambda^\text{NL}_{Ti}(N) \), and \( \lambda^\text{NL}_{Ni}(N) \), derived using the formulas in (1) and (2), do not contain any terms of \( N \), we can treat these parameters as constant when taking the derivative with respect to \( N \). Hence, the derivative of the right hand side of (19) with respect to \( N \) is

\[
\frac{\partial}{\partial N} \left( \frac{1 - \delta}{1 - \delta \phi \sigma^\text{NL}_T} \left( \lambda_{11}(N)\pi - \lambda^\text{NL}_{Tc}(N)\pi + \frac{N}{N - \delta(N - 1)} \left( \lambda_{11}(N)\pi - \lambda^\text{NL}_{Ni}(N)\pi \right) \right) \right)
\]

Substituting in the values of \( \lambda_{11}(N) \) and \( \lambda^\text{NL}_{Ni}(N) \), we can show that

\[
\lambda_{11}(N)\pi - \lambda^\text{NL}_{Ni}(N)\pi = \sigma^L_{\pi} \left( \sigma^\text{NL}_T - \sigma^\text{NL}_{Ni} \right) \sum_{k=0}^{N-1} \frac{1}{(k + 2)(k + 1)} \left( \frac{N - 1}{k} \right) \left( 1 - \sigma^L_{\pi} \right)^{-k} \left( \sigma^L_{\pi} \right)^{k} < 0
\]
Hence, since $0 < \delta < 1$ and $0 < \sigma_i^{NL} < 1$, this means that the derivative of the right hand side of (19) with respect to $N$ is negative and the right hand side of (19) is increasing in $N$. That is, as $N$ increases, there will be fewer values of $c_i$ for which licensing is an equilibrium and hence the likelihood that licensing is an equilibrium is decreasing in $N$.

Proof of Lemma 3

From (14) and (15), in the game with experiential learning where $\phi = 1$ and $N = 1$, co-promotion will be an equilibrium outcome if

$$c_i \geq \frac{1 - \delta}{\delta \sigma_{\text{CP}}^\sigma} \left( 2 \lambda_{11}(1) \pi - \lambda_{\text{CP}}^\sigma (1) \pi - \lambda_{\text{CP}}^{NL} (1) \pi \right)$$

and

$$c_i \leq \lambda_{\text{CP}}^\sigma (1) \pi + \lambda_{\text{CP}}^{NL} (1) \pi + 2 \left( \frac{\sigma_{\text{CP}}^\sigma - \sigma_{\text{CP}}^{NL}}{1 - \delta(1 - \sigma_{\text{CP}}^{NL})} \right) \lambda_{11}(1) \pi \frac{1 - \delta(1 - \sigma_{\text{CP}}^{NL})}{1 - \delta(1 - \sigma_{\text{CP}}^{NL})} \lambda_{11}(1) \pi + 1 - \delta \left( \frac{1 - \sigma_{\text{CP}}^\sigma}{1 - \delta(1 - \sigma_{\text{CP}}^{NL})} \right) \left( \lambda_{\text{CP}}^{NL} (1) \pi + \lambda_{\text{CP}}^{NL} (1) \pi \right)$$

Combining these two constraints and substituting the values of $\lambda_{11}(N)$ and $\lambda_{\text{CP}}^{NL} (N)$ from equations (1) and (2) this means that co-promotion will be an equilibrium outcome if

$$\lambda_{\text{CP}}^\sigma (1) \pi + \lambda_{\text{CP}}^{NL} (1) \pi + 2 \left( \frac{\sigma_{\text{CP}}^\sigma - \sigma_{\text{CP}}^{NL}}{1 - \delta(1 - \sigma_{\text{CP}}^{NL})} \right) \lambda_{11}(1) \pi \frac{1 - \delta(1 - \sigma_{\text{CP}}^{NL})}{1 - \delta(1 - \sigma_{\text{CP}}^{NL})} \lambda_{11}(1) \pi + 1 - \delta \left( \frac{1 - \sigma_{\text{CP}}^\sigma}{1 - \delta(1 - \sigma_{\text{CP}}^{NL})} \right) \left( \lambda_{\text{CP}}^{NL} (1) \pi + \lambda_{\text{CP}}^{NL} (1) \pi \right) \geq 0$$

Substituting in the values of $\sigma_{\text{CP}}^\sigma = \sigma_{\text{CP}}^{NL} = \sigma_{\text{CP}}^{\text{CP}} = \sigma_{\text{CP}}^{\text{NL}} = \sigma_{\text{CP}} = \sigma_{\text{CP}}^{\text{CP}} = \sigma_{\text{CP}}^{\text{NL}} = \sigma_{1} = \sigma_{\text{CP}}^{\text{NL}} = \sigma_{\text{CP}} = \sigma_{\text{CP}}^{\text{CP}} = \sigma_{\text{CP}}^{\text{NL}} = \sigma_{0} < \sigma_{1}$ and

$$\sigma_{\text{CP}} = \frac{1}{2} (\sigma_{0} + \sigma_{1})$$

we can show that
\[(1 - \sigma_i)(\sigma_i - \sigma_o)(\delta\sigma_i - 1 + \delta)(\delta\sigma_o + \delta\sigma_i + 2 - 2\delta) \geq 0\]

which is true when \(\sigma_i \geq \frac{1 - \delta}{\delta}\).

**Proof of Proposition 2**

From (17), in the game with experiential learning where \(\phi \leq 1\) the parties will choose co-promotion over licensing in equilibrium if

\[c_i \geq \frac{1 - \delta}{\delta\phi\sigma_{i}^{CP}} \left( \frac{2\lambda_i(1)\pi - \lambda_{i}^{CP}(1)\pi - \lambda_{i}^{CP}(1)\pi}{1 - \delta + \delta\phi} \right)\]

The derivative of the right hand side with respect to \(\phi\) is

\[= \frac{\partial}{\partial \phi} \left( \frac{1 - \delta}{\delta\phi(1 - \delta + \delta\phi)} \frac{2\lambda_i(1)\pi - \lambda_{i}^{CP}(1)\pi - \lambda_{i}^{CP}(1)\pi}{\sigma_{i}^{CP}} \right)\]

\[= \left(2\lambda_i(1)\pi - \lambda_{i}^{CP}(1)\pi - \lambda_{i}^{CP}(1)\pi\right) \frac{-\delta\sigma_{i}^{CP}(1 - \delta)(1 - \delta + 2\delta\phi)}{\left(\delta\sigma_{i}^{CP}\phi(1 - \delta + \delta\phi)\right)^2}\]

Since \(\sigma_{i}^{CP} \in (0,1), \delta \in (0,1),\) and \(\phi \in (0,1]\), the right-hand side of (17) is always negative. This means that the threshold level of transaction costs at which it becomes more profitable to co-promote goes down as \(\phi\) increases. Hence co-promotion becomes more likely relative to straight licensing as \(\phi\) increases, or the likelihood of co-promotion is increasing in \(\phi\).


