Technology and Commercialization Strategies: A Start-up's Choice to Compete or Cooperate

Innovation is crucial to long-term economic growth and welfare, and high-technology start-up firms are major contributors to innovation. One important aspect of the innovation process is obtaining financing for commercialization of the innovation. Very often a start-up that achieves success in the research and development (R&D) stage will require significant additional financing in order to produce and sell the product at commercial scale. For successful early stage start-ups that require outside infusions of financing, the two major alternatives are to be acquired by an incumbent firm or to undertake an initial public offering (IPO). A starting point for my research is the idea that the choice to seek an acquisition or an IPO, which I refer to as the start-up's commercialization strategy, is inherently about whether to cooperate or compete with incumbents in an industry.

Many start-ups protect their inventions with patents. Patents are particularly suitable for start-ups that need to disclose their inventions to outside investors.[1] They also have many traits that make them especially tractable for empirical analysis. I use patent statistics, including patent counts and citation patterns, to shed light on the type of invention a start-up has chosen to pursue. I refer to this choice regarding the type of invention to pursue as the start-up's technology strategy. The objective of this research project is to understand the relationship between a start-up's technology and commercialization strategies.[2] This project is the foundation of a more extensive research agenda focused on the impact of policy on high-technology entrepreneurial firms.

I propose a formal model of the causal relationship between a start-up's technology strategy and its commercialization strategy. In the model, a firm that intends to seek an IPO and compete as a stand-alone entity must invest in developing the full system of components necessary to produce a sellable product in its sector. On the other hand, a firm that intends to get acquired should specialize in developing a high-quality single component. The model therefore emphasizes that a start-up's technology and commercialization strategies are two facets of the same strategic choice – whether to cooperate or compete.

I use near-population data on successful patent-holding start-ups from 1986-2006 to show that the predictions of the model are consistent with the data.[3] Patent statistics and the choice to IPO or be acquired are endogenously determined in the model. As such, I derive regression coefficients directly from the equilibrium strategies of the start-ups and incumbents.[4] The model also predicts a start-up's optimal response to changes in its environment. In 2002, the Sarbanes-Oxley Act raised the cost of IPOs relative to acquisitions. The model predicts that firms should respond by favoring component specialization and pursuing acquisitions. Preliminary results indicate that this prediction is supported in the data.[5] This research therefore allows us to understand an important unintended consequence of this policy.

I focus on innovation with respect to inputs, and allow for both complementarities and substi-

[1] Other forms of intellectual property protection include copyright, trade secrets, trademarks, and industrial designs. Patents must be filed with a central authority (the patent office), must include citations to relevant prior art, are classified into classes, and are subjected to external review for validity.

[2] Prior research that has examined the relationship between technology characteristics and commercialization strategy includes Teece (1986) and Gans and Stern (2003).

[3] Data for acquisitions are taken from SDC Mergers & Acquisitions, and may not include many low-value acquisitions. Data for IPOs and patents are taken from GNI New Issues and the NBER Patent Data, and represent the population for new listings on the NYSE, Nasdaq, and Amex exchanges and for utility patents, respectively. In total this project requires the integration of 7 major datasets ranging in size from 10,000 to 30million observations.

[4] Without assuming specific functional forms for production functions, distributions, and so forth, the signs and relative magnitudes of various regression coefficients can be directly calculated from the model.

[5] For clean identification, it is necessary that some firms experienced a different rise in costs from others. Possibly biotechnology firms, which were already highly regulated, faced a relatively lower rise in costs than IT firms.

tution effects between inputs.[6,7] Specifically, I suppose firms operating in the same sector as the start-up have a production function $y = f\{A, B\}$, where A and B are two components protected by a patent or patents. A and B together form a system of components. Firms in another sector use partially overlapping components: $y = f\{B, C\}$. The production function y exhibits complementarities. A patent on an A component cites all extant A component patents, and so forth, to reflect the requirement that patents must cite all relevant prior art. Start-ups and incumbents both draw components from a quality distribution, with the expected quality dependent on expenditure. Components of the same type are therefore substitutes for one another. A start-up has limited capital and can choose to spread its R&D investment across a system of both components or devote all of its resources to producing a single component with higher expected quality.

The model captures the patenting and commercialization processes as well as the innovation process. A start-up decides whether or not to patent an invention for a cost per patent given the component draw, the expected future draws of incumbents, and the available public domain technology. After incumbents have drawn new technologies, a start-up makes offers to sell itself to acquirers or enters the market with an initial public offering. The model affords market power gains to acquirers by using different value functions for their value with and without entry by the start-up. This is offset by a cost that arises from the path dependent nature of innovation. An acquirer that buys a start-up uses a weighted average of its components and the recently acquired components in its production function.[8] As a result, a start-up with higher quality draws on both components than the incumbents will choose to patent both components then IPO as it is more valuable as a stand-alone competitor.

Two new dimensions of patent citations are explicit in the model. I distinguish between citations to patents under active property-right protection and citations to expired patents.[9] Citations between protected patents arise when the start-up or incumbents patent a new component and another player has already patented the same component in a previous stage of the game. Inventions covered by expired patents lie in the public domain. They are exogenously provided in the model and are available to the start-up and incumbents alike for use in their production functions. The model also makes a crucial distinction between patent citations to firms in the same sector as the start-up and firms in different sectors. The empirical results to date (see the table below) show that these new measures unmask an impressive amount of previously unobserved heterogeneity.[10]

According to the theory, a startup files for a greater number of patents when it has a system of components, and this is positively correlated with an IPO.[11] Having a system also results in making and receiving more citations to an incumbent in the same sector as the start-up. Furthermore, as citations reflect component substitution, a greater number of citations received is correlated with

[6] To the best of my knowledge this is the first formal model in the literature that explicitly examines the compete/cooperate consequences of patented innovations. However, other formal innovation models (e.g., Henderson 1993) could be repurposed to this end. The patent thicket literature, notably Cockburn and MacGarvie (2006), has advanced informal arguments where patents represent complementary inputs.

[7] Lerner (1994) and Ziedonis (2004) have previously operationalized measures of citations to convey substitution and complementary effects between patents, respectively.

[8] The acquirer may have assets in place to support its old technology that it will need to adjust or dispose of and there may be knowledge about the invention beyond the patent that the acquirer needs to learn.

[9] Patent protection can lapse because a patent has reached the end of its statutory term (17 or 20 years, before and after June 1995 respectively), renewal fees have not been paid (due $3\frac{1}{2}$, $7\frac{1}{2}$, and $11\frac{1}{2}$ years after a patent is granted), patents have been deemed invalid by the USPTO or courts, or terminal disclaimers have been made.

[10] The additional explanatory power of decomposing citation counts into in-sector and out-of-sector citation counts is roughly equal to that of either year or sector fixed effects.

[11] Equivalently, a greater number of patent claims should be correlated with an IPO.

a reduction in firm value.[12] These predictions are strongly supported in the data.[13]

Explanatory variables in bold are citation measures. For the first two columns they are measures of citations-made, and for the remaining columns measures of citations-received. All estimations include the number of years between patent application(s) and the liquidity event, and sector × year and modal patent class fixed effects. Logit estimations of the choice to IPO include firm value controls, and OLS estimates of firm value include an IPO variable, as well as citation age controls. Coefficients are reported with heteroskedastically robust standard errors in parentheses. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.1 levels respectively.

	Log Citations Made		**Log Citations Rec'd**		
Dependent Variable:	$y = \begin{cases} 1 & \text{if IPO} \\ 0 & \text{if Acquired} \end{cases}$		$y = \begin{cases} 1 & \text{if IPO} \\ 0 & \text{if Acquired} \end{cases}$		**Log Value**
Log No. Patents	0.619*** (0.054)	0.073 (0.102)	0.649*** (0.055)	0.122 (0.104)	0.371*** (0.041)
Avg. Renewals	0.257*** (0.056)	0.039 (0.097)	0.312*** (0.064)	0.079 (0.102)	0.130*** (0.041)
To Protected	0.163** (0.083)		-0.177** (0.074)		
In-Sector		0.986*** (0.182)		1.162*** (0.175)	-0.156*** (0.058)
Out-of-Sector		-0.555*** (0.130)		-0.722*** (0.116)	-0.096** (0.041)
To Expired	0.015 (0.102)		0.108 (0.092)		
In-Sector		0.121 (0.308)		0.921** (0.405)	-0.097 (0.123)
Out-of-Sector		0.147 (0.197)		-0.431*** (0.149)	0.166** (0.068)
Full Controls	yes	yes	yes	yes	yes
Constant	0.284 (0.463)	-2.840*** (0.962)	0.481 (0.520)	-2.874*** (0.932)	2.770*** (0.315)
(Pseudo-)R^2	0.29	0.52	0.30	0.52	0.50
No. Observations	3,891	1,964	3,484	1,964	2,253

Overall, this research formalizes and tests our understanding of the relationship between a start-up firm's technology and commercialization strategies. The strength and consistency of the empirical results suggest that the theory captures important insights into how firms choose which inventions to pursue and whether to seek an IPO or an acquisition. It also informs the meaning of existing patent statistics, develops two new citation-based measures, and shows that considerable information was previously hidden in aggregate citation counts.[14] Finally, the key contribution of this research is that it shows that both technology strategy and commercialization strategy can be viewed as aspects of a single decision – to cooperate or compete with an industry incumbent.

Cockburn, I.M. and MacGarvie, M.J. (2006). Entry and patenting in the software industry. NBER Working Paper.

Gans, J.S. and Stern, S. (2003). The product market and the market for ideas: commercialization strategies for technology entrepreneurs. Research policy, vol. 32 (2), pp. 333–350.

Hall, Bronwyn H., Jaffe, Adam, and Trajtenberg, Manuel (2005). Market value and patent citations. The RAND Journal of Economics, vol. 36 (1), pp. pp. 16–38.

Henderson, Rebecca (1993). Underinvestment and incompetence as responses to radical innovation. The RAND Journal of Economics, vol. 24 (2), pp. pp. 248–270.

Lerner, J. (1994). The importance of patent scope: an empirical analysis. The RAND Journal of Economics, pp. 319–333.

Teece, D.J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy, vol. 15 (6), pp. 285–305.

Ziedonis, R.H. (2004). Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms. Management Science, pp. 804–820.

[12] This prediction stands in stark contrast to Hall et al. (2005) and others who have studied the value implications of citations for non-start-ups.

[13] Other models based on complementarities and/or substitution between patented inputs are not consistent with the data. For example, the results are not consistent with a patent thicket model. In such a model citations reflect complementary input requirements, and a greater exposure to a thicket (more citations made in the start-up's sector) would provide a strong incentive for a firm to seek an acquisition by an incumbent who could navigate the thicket through pre-existing cross-licensing agreements or other arrangements.

[14] I am very familiar with the large literature on patent statistics and, for the last three years, have been maintaining and contributing to the NBER Patent Data Project under Iain Cockburn. A final goal of this research is to provide the measures and data needed to replicate and expand upon my results back to the academic community.