University Invention, Entrepreneurship, and Start-Ups

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Abstract

The Bayh-Dole Act (1980) allows U. S. universities to own and license inventions arising from federally-funded research by their faculty. We examine the question of when commercialization of university inventions occurs in start-up firms instead of established firms. We construct a theoretical model that predicts that start-ups are more likely if their opportunity cost of development and commercialization is lower, due to less profitable alternatives, or if the university's technology transfer officer's opportunity cost of searching for a partner among established firms is greater Using AUTM data for 1993-2001, we find that inventor quality, cumulative gross licensing royalties, and the presence of a medical school have a negative impact on start-up activity, but lagged disclosures, current licenses, cumulative active licenses, and the age of the TTO have significant, positive effects. We find little evidence that interest rates affect start-up activity, but some evidence that upward movements in the Dow or Nasdaq positively affect start-ups.

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1 Introduction

The Bayh-Dole Act led to an explosion in the growth of technology transfer offices in universities, as well as a substantial increase in the commercialization of university inventions. Although initially most of this activity took the form of license agreements with established firms, recently there has been an increase in commercialization via new firms, or start-ups. This paper examines reasons for the commercialization of university inventions through start-up firms as opposed to established firms.

Technology transfer officers (TTOs) are responsible for making good-faith efforts to commercialize university inventions. This process begins when a faculty member discloses a potential invention to the TTO, who then tries to find a partner for commercialization. If the TTO is unable to find an established firm willing to purchase a license for the technology, then it shelves the invention. That is, the TTO returns it to the inventor, who may then seek venture capitalists or angel investors to help fund a start-up firm in order to attempt to commercialize the invention. In fact, the TTO may return it to the inventor immediately, without even trying to find a firm to license it. In this event, the TTO may assist the inventor in searching for an investor to fund a start-up, but typically TTOs focus their efforts on licensing inventions to established firms.

We formalize this by developing a game-theoretic model of university licensing. It begins when the inventor discloses an invention to the TTO, which first decides either to shelve the invention or to search for an established firm to which it offers a license contract. If a contract is offered, then the firm decides either to accept or reject the contract. If it accepts, then it pays a fixed fee and a period of further development follows, in which both the inventor and the licensee may expend effort to improve the probability of success. The firm then decides either to terminate the project, after which the TTO shelves the invention, or to expend the resources necessary to attempt to commercialize it, after which its success or failure becomes common knowledge. If it succeeds, the firm produces and pays royalties. If the TTO shelves the invention, the inventor may attempt to find an investor for a start-up firm to pursue licensing, further development, and commercialization. The TTO may assist in this process, but does so with a minimal expedniture of effort.

The model provides two main implications regarding commercialization by start-up firms rather than established firms. First, if the TTO's utility cost of searching is the same for both types of firms, then start-ups occur in equilibrium only if a start-up firm earns greater expected profit, gross of any license payments, than an established firm, so that the TTO can earn greater net utility from licensing to a start-up under the optimal contract. This occurs if a start-up firm has an advantage in the cost of additional development or commercialization. Although established firms may have cost advantages for inventions that are closely related to their current product line, they may not for those that do not fit well in their existing product lines. These costs include the potential profits from foregone opportunities, and established firms typically have alternatives that are more closely related to their current business, and therefore more profitable. Moreover, venture capitalists routinely deal with new products and processes, so they may well have better access to and/or information about the expertise needed to develop and commercialize embryonic inventions, which would provide a start-up firm with a cost advantage. Similarly, inventor-founded start-ups may well have cost advantages due to the inventor's superior knowledge of the technology, which can limit transactional and informational problems (Shane 2002). Also, if the start-up has a lower opportunity cost of development effort, then it may provide greater effort in the development stage. Because inventor and firm effort are strategic complements, greater firm effort induces greater inventor effort, and thus a greater probability of success and greater expected profit for the start-up firm. The second main implication is that licensing to a start-up can occur, even if expected profit is same for both types of firms, simply because the TTO's opportunity cost of searching for an established firm as a licensee is greater. This can occur if the TTO has a pool of higher-quality disclosures available for commercialization, so less attractive ones are immediately shelved.

Several empirical implications follow immediately from the theory. Essentially, we are more likely to observe commercialization of university inventions by start-up firms in situations in which start-ups are more likely to have a cost advantage in the development or commercialization, or in which the opportunity cost of TTOs in searching for an established firm as a partner is higher. We summarize these in terms of characteristics of the inventor, the TTO, and the invention, and financial market conditions. Generally, we expect more licensing to start-up firms for lower quality inventors, TTOs with less experience and/or expertise, less applied inventions, and more favorable financial market conditions for venture capitalists and other investors.

Our empirical analysis uses AUTM data for 1993-2001 to examine commercialization of inventions by start-up firms. We estimate equations for both the annual number of start-ups per university and the cumulative number of start-ups in each year. In general, unlike Di Gregoriao and Shane

(2003), our results provide evidence that inventor quality has a negative impact on start-up activity. It appears that universities with higher quality faculty have less need to commercialize their inventions through start-ups. We also find some evidence that this relationship is convex, so as quality decreases, the number of start-ups increases at an increasing rate. We also find that lagged disclosures, current licenses, cumulative active licenses, and the age of the TTO have significant, positive effects on start-up activity. Conversely, cumulative gross licensing royalties negatively affects start-up activity. We find no evidence that the ratio of industrial to federal research support predicts start-up activity, but universities with medical schools generate less start-up activity. Finally, we find little evidence that interest rate changes affect start-up activity, but some evidence that general market conditions do. When we include interest rates in our benchmark equations, the sign of the estimated coefficient is ambiguous. Although the estimated coefficients for the Dow and NASDAQ indices were positive, they were not significant. Nevertheless, when we regress only these variables on start-ups, the coefficients for the Dow and NASDAQ are positive and significant, and while that for the interest rate is negative but not significant.

Our results contribute to the small but growing theoretical literature on the licensing of university inventions. The theoretical literature has predominantly focused on the effects of the Bayh-Dole Act, and the behavior of inventors and TTOs: Jensen and Thursby (2001), Lach and Shankerman (2002), Jensen, Thursby, and Thursby (2003), Thursby, Thursby, and Decheneaux (2004), Hoppe and Ozdenoren (2004), and Macho-Stadler, Perez-Castrillo, and Veugelers (2004). One exception to this is Jensen and Thursby (2004), who study the effects of increased incentives to commercialize university research on the trade-off between applied and basic research, and the quality of education. What distinguishes our theoretical model is that all previous efforts have simply focused on the licensing or commercializing of the invention to some firm, rather than determining the conditions under which commercialization occurs through a start-up firm instead of an established firm.

Our results also contribute to the now extensive empirical literature on the commercialization of university research and start-ups. Much of the literature on university invention has abstracted from examining the role of university inventors and TTOs. Exceptions include Bercovitz *et al.* (2001) and Siegel *et al.* (1999), who take an organizational perspective, Thursby *et al.* (2001), Thursby and Thursby (2001), Jensen, Thursby, and Thursby (2003), and Thursby, Thursby, and Decheneaux (2004), who examine the role of TTOs in structuring license contracts, and Lach and Shankerman

(2002), who study the number and value of inventor disclosures. Our work adds to this literature as our approach considers quality of faculty and its effect on the choice between commercialization by established firms and start-up firms.

Shane has examined factors influencing the performance of start-ups using data on inventions by MIT faculty. He shows that the formation of start-ups is fostered by both recognition of business opportunities by inventors (Shane 2000) and the presence of technological opportunities (Shane 2001). Shane and Stuart (2002) find that start-ups are more likely to succeed if the founders have relationships with venture capitalists. Di Gregoriao and Shane (2003) examine start-up formation across US universities, using AUTM data for the period 1994-1998, and find a positive relationship between start-up formation and faculty quality, as measured by the Gourman Report (our empirical analysis, in part, updates and extends this study). The latter two studies include financial market factors in the form of availability of nearby sources of venture capital and IPOs, but do not examine more general measures of financial market activity, or measures of TTO experience. Finally, Shane (2002) compares MIT inventions licensed to established and start-up firms. He finds that licensing to inventor-founded start-ups is more likely when patents are ineffective at preventing information problems (such as moral hazard and adverse selection), because the inventor's superior knowledge of the technology precludes such problems in start-ups. However, he also finds that licenses to start-ups perform poorly compared to licenses to established firms, and concludes that licensing to start-ups on a second best solution for TTOs. This supports our assumption that TTOs generally prefer to license to established firms, and put far less effort into searching for start-up licensees.

The remainder of the paper includes the theoretical model and basic equilibrium results in Section 2, and the empirical implications of this analysis in Section 3. Section 4 discusses the data, and Section 5 provides the empirical results. Section 6 concludes.

2 The Theoretical Model

The model is a reasonably straightforward compilation and extension of those in Jensen and Thursby (2001) and Jensen, Thursby, and Thursby (2003). We model the problem as a multistage game with four players: the TTO, the inventor, an established firm, and an investor/entrepreneur. The game unfolds over time with the following sequence of actions. It begins when the inventor discloses an invention to the TTO. The TTO first decides either to shelve the invention (i.e., return it to the inventor), or to search for an established firm to which it offers a license contract. If a contract is offered, then the firm decides either to accept or reject the contract. If it accepts, it pays a fixed license fee, $M \geq 0$, and then a period of further development follows. If it rejects the contract, the TTO shelves the invention. This development results in an updated probability of success, which is common knowledge. The firm then decides either to terminate the project, after which the TTO shelves the invention, or to expend the resources necessary to attempt to commercialize it, after which whether the invention succeeds becomes common knowledge. If it fails, the game ends. If it succeeds, the firm produces and pays total royalties of $R \geq 0$.

In the development period, the inventor and the firm may expend further effort to increase the probability of success. We assume these efforts are not contractible, but instead are chosen at the beginning of the development period (after the licensing agreement has been made) as the equilibrium outcomes $e_F \geq 0$ and $E_F \geq 0$ of a noncooperative subgame between the inventor and licensee, which in general will depend upon the contract. That is, equilibrium efforts are $e_F^* = e_F^*(R_F, M_F)$ and $E_F^* = E_F^*(R_F, M_F)$.

As is well-known by now, university inventions are typically embryonic. Their commercial potential is uncertain, and the likelihood of their success is very small. We assume that the probability of success $p(e_F, E_F; Q, H)$ depends not only on the efforts, but also on a measure of the quality of the inventor, Q, and a measure of the historical success of the TTO, H. We assume that p is increasing in not only in the efforts, but also inventor quality and past TTO success. It is evident that efforts and inventor quality are inputs in the "production" of a probability of success Including TTO success as an input as well implies that, *ceteris paribus*, an invention drawn at random from a faculty member at a university with a superior track record of success is more likely to be a success. We also assume that p is jointly concave in all its arguments, and that $p \in (0,1)$ for all $(e, E; Q, H)$. Finally, we assume that additional effort by the firm (in the form of more or better equipment, for example) should increase the marginal impact of inventor effort on the probability of success, $\frac{\partial^2 p}{\partial e \partial E} > 0$. That is, effort by the inventor and firm are "complements" in development, in the sense that they complement each other in the production of a positive probability of success.

If additional development occurs and the invention is a success, then the firm chooses output to maximize its profit (net of any license fees). In general, because the firms's marginal cost depends on the royalty rate, but not the fixed fee, its maximal output is decreasing in the royalty rate but does not depend on the fixed fee. If $r \geq 0$ is the royalty rate per unit of output, denote profit-maximizing output by $x(r)$. We assume that $x(0) > 0$ and $x'(r) < 0$, and that total royalty revenue $R = rx(r)$ is strictly concave in r and takes a unique maximum at some positive but finite value.[1] Because the "effort" provided by the firm can include materiel and personnel as well as cash grants, we denote the cost of its effort by $C_F(E_F)$, which we assume is increasing at an increasing rate: $C_F(0) = 0$, $C_F' > 0$, and $C_F'' > 0$. Finally, the firm must also pay a lump-sum cost to attempt to commercialize the invention, $K_F > 0$. Thus, if $\Pi(x(r))$ is the firm's maximized profit (gross of royalty payments) for any royalty rate r, then its expected payoff from accepting a contract (R_F, M_F) is

$$P_F(e_F, E_F) = p(e_F, E_F; Q, H)[\Pi(x(r_F)) - R_F] - M_F - C_F(E_F) - K_F, \quad (1)$$

where r_F is the royalty rate associated with the contract (R_F, M_F) (i.e., $R_F = r_F x(r_F)$).The firm accepts this contract and attempts to commercialize the invention (after development) if $P_F(e_F, E_F) \geq 0$.

Conversely, suppose that the TTO shelves the invention, by which we mean the TTO returns it to the inventor and expends effort in searching for a licensee. This can occur initially after disclosure, or after rejection of a contract offer by a potential licensee.[2] In this case, an attempt to commercialize the invention occurs only if a venture capitalist or angel investor can be found to provide the effort required to create a new firm, or start-up, based on the invention, as well as to assist in additional development. The TTO may assist in the process of searching for an investor and start-up firm as a licensee, but with a minimal level of effort. The effort expended by the inventor may be greater in this case, as it typically includes search for investors as well as additional development. To save on notation, we let e_S and E_S denote the total efforts expended by the inventor and the venture capitalist.

Nevertheless, if a start-up is created, then it is the job of the TTO to offer this firm a license contract for the use of the invention. We assume it takes the same form, a combination of royalty and fixed fee, (R_S, M_S), where the

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[1] These assumptions on royalty revenue hold for a broad class of new process innovations licensed to a single firm (including, but not limited to, the case of linear demand and constant marginal cost).

[2] The firm could agree to a contract, and then refuse to attempt to commercialize it after the development period if it is indifferent, $P_L(R_L, M_L) = 0$. In this case we assume the firm attempts the commercialization.

royalty rate is r_S and total royalties are $R_S = r_S x(r_S)$. Again we assume these efforts are the equilibrium outcomes e_S and E_S of a noncooperative game between the inventor and venture capitalist, which in general depend upon the contract, $e_S^* = e_S^*(R_S, M_S)$ and $E_S^* = E_S^*(R_S, M_S)$. The start-up firm's cost of effort is $C_S(E_S)$, which we again assume satisfies $C_S(0) = 0$, $C_S' > 0$, and $C_S'' > 0$. If its lump-sum cost to attempt to commercialize the invention is $K_S > 0$, then its expected payoff from accepting the contract (R_S, M_S) is

$$P_S(e_S, E_S) = p(e_S, E_S; Q, H)[\Pi(x(r_S)) - R_S] - M_S - C_S(E_S) - K_S. \quad (2)$$

The venture capitalist assists in the creation of a start-up firm, which accepts this contract and attempts to commercialize the invention (after development), if $P_S(e_S, E_S) \geq 0$.

Assume that, if additional development occurs, then for each $j = F, S$, $\hat{E}_j$ is the maximum effort that firm j could devote to development. The continuity and strict concavity of each P_j guarantees that it is maximized at some $E_j \in [0, \hat{E}_j]$, and so there exists a firm j best-reply function $b_j(e_j)$. Moreover, $\frac{\partial P_j(e_j,0)}{\partial E_j} > 0 > \frac{\partial P_I(e_j,\hat{E}_j)}{\partial E_j}$ is sufficient to guarantee that P_j has an interior maximum at some $E_j \in (0, \hat{E}_j)$, in which case the first order necessary condition is:

$$\frac{\partial P_j}{\partial E_j} = \frac{\partial p}{\partial E_j}[\Pi(x(r_S)) - R_S] - 1 = 0. \quad (3)$$

It is worth noting that the firm expends effort on additional development, independently of the inventor, only if it can independently increase the probability of success.

The inventor's utility function takes the form $U_I(Y_I, \vartheta) - V_I(e)$, where Y_I is his income and ϑ is an indicator function that equals 1 if a license is sold and 0 if not. That is, the inventor gains utility both from income and the prestige associated with the successful sale of a license (to an established firm or a start-up),[3] but suffers disutility from the effort in further development, $V_I(e)$. Naturally we assume positive but nonincreasing marginal utility from income (the inventor can be risk-neutral or risk-averse), positive marginal utility from sale of a license, and positive and increasing marginal disutility of effort. That is, $\frac{\partial U_I}{\partial Y_I} > 0 \geq \frac{\partial^2 U_I}{\partial Y_I^2}$, $U_I(Y_I, 1) > U_I(Y_I, 0)$, $V_I' > 0$, and

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[3] See Stephan (1996) for a survey of empirical support for the assumption that inventors also receive utility from nonpecuniary sources, such as seeing an invention licensesd or patent granted.

$V_I'' > 0$. Thus, if α_I is his share of license income, then for each $j = F, S$, his expected utility is

$$\begin{aligned} P_I(e_j, E_j) &= p(e_j, E_j; Q, H)U_I(\alpha_I(M_j + R_j), 1) + \\ &\quad (1 - p(e_j, E_j; Q, H))U_I(\alpha_I(M_j + R_j), 1) - V_I(e_j). \quad (4) \end{aligned}$$

Now assume that $\hat{e}$ is the maximum effort that the inventor could devote to development. Then for each $j = F, S$, the continuity and strict concavity of P_I guarantees that it is maximized at some $e_j \in [0, \hat{e}]$, and so there exists an inventor best-reply function $b_I(E_j)$. Moreover, $\frac{\partial P_I(0,E_j)}{\partial e} > 0 > \frac{\partial P_I(\hat{e},E_j)}{\partial e}$ is sufficient to guarantee that P_I has an interior maximum at some $e_j \in (0, \hat{e})$, in which case the first order necessary condition is:

$$\frac{\partial P_I}{\partial e_j} = \frac{\partial p}{\partial e_j}[U_I(\alpha_I(M_j + R_j), 1) - U_I(\alpha_I M_j, 1)] - V_I'(e_j) = 0. \qquad (5)$$

It is worth noting that, as in Jensen and Thursby (2001), the inventor expends effort on additional development only if the royalty rate is positive.[4]

Theorem 1 *Under the assumptions on the payoff functions and strategies, for each $j = F, S$ and given contract (R_j, M_j), there exists a Nash equilibrium $(e_j^*(R_j, M_j), E_j^*(R_j, M_j))$ for the development subgame between the firm and inventor. Furthermore, the equilibrium is:*
(i) No development, $e_j^* = E_j^* = 0$, if $\frac{\partial P_I(0,\hat{E}_j)}{\partial e} < 0$ and $\frac{\partial P_j(\hat{e},0)}{\partial E_j} < 0$;
(ii) Both inventor and firm j expend effort in development, $e_j^* > 0$ and $E_j^* > 0$, if $\frac{\partial P_j(0,0)}{\partial E_j} > 0$ and $\frac{\partial P_I(0,0)}{\partial e_j} > 0$; and
(iii) Unique and locally stable if and only if $b_I'(b_j'(e_j^*)) < 1$.

Inventor and firm efforts, whenever they are interior, are strategic complements because they are complements in development: that is, $\frac{\partial^2 p}{\partial e \partial E} > 0$ implies $b_I'(E_j) > 0$ and $b_j'(e_j) > 0$. As long as their best-reply functions have the appropriate relative slopes, as depicted in figure 1, then there is a unique and locally stable equilibrium in which development occurs and each contributes to that development, $e_j^*(R_j, M_j) > 0$ and $E_j^*(R_j, M_j) > 0$ for each $j = F, S$.

The TTO's utility function is $U_T(Y_T, \vartheta) - V_{Tj}(Q, H)$, where Y_T is income and ϑ is the indicator function above. That is, the TTO also gains utility both from income and the prestige associated with the successful sale of

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[4] If $r_j = 0$, then $e_j = 0$ because he earns his share of the fixed fee, $\alpha_I M$, whether he expends any effort or not, and the marginal disutility of effort is positive, $V_I'(0) > 0$.

a license, but suffers disutility from the search for a licensee. Again we assume positive but nonincreasing marginal utility from income, and positive marginal utility from sale of a license:$\frac{\partial U_T}{\partial Y_T} > 0 \geq \frac{\partial^2 U_T}{\partial Y_T^2}$ and $U_T(Y_T, 1) > U_T(Y_T, 0)$. We also assume that the utility cost of search depends on the type of licensee, a measure of the quality of the inventor, and a measure of the historical success of the TTO. In particular, we assume the disutility of search is decreasing at a nonincreasing rate in inventor quality and past TTO success: $\frac{\partial V_{Ti}}{\partial Q} < 0$, $\frac{\partial^2 V_{Ti}}{\partial Q^2} \leq 0$, $\frac{\partial V_{Ti}}{\partial H} < 0$, and $\frac{\partial^2 V_{Ti}}{\partial H^2} \leq 0$. We further assume that, as indicated above, the TTO may assist the inventor in the process of searching for an investor for a start-up, but with much less effort than it uses in searching for an established firm as a licensee. That is, *ceteris paribus*, the utility cost of licensee search is smaller for a start-up firm: $V_{TF}(Q, H) > V_{TS}(Q, H) \geq 0$. For $j = F, S$, the TTO's expected payoff from licensing with contract (R_j, M_j) to firm j is then

$$\begin{aligned} P_T(R_j, M_j) &= p(e_j^*, E_j^*; Q, H) U_T(\alpha_T(M_j + R_j), 1) + \\ & \quad [1 - p(e_j^*, E_j^*; Q, H)] U_T(\alpha_T M_j, 1) - V_{Tj}(Q, H), \end{aligned} \tag{6}$$

where $\alpha_T \in (0, 1)$ is its share of license income and $\alpha_T + \alpha_I \leq 1$. If a potential licensee is located, the TTO's problem is to choose a contract to maximize its expected payoff (6) subject to the licensee's participation constraint, or

$$\max_{(R_j, M_j)} P_T(R_j, M_j) \text{ s.t. } P_j(e_j^*, E_j^*) \geq 0. \tag{7}$$

We denote these optimal choices by (R_j^*, M_j^*). If a license contract with positive royalty rate and fixed fee is sold, then the first order conditions are that the participation constraint holds and

$$\frac{\frac{\partial P_T}{\partial R_j}}{\frac{\partial P_T}{\partial M_j}} = \frac{\frac{\partial P_j}{\partial R_j}}{\frac{\partial P_j}{\partial M_j}}. \tag{8}$$

This condition, of course, requires a tangency between the expected-payoff indifference curves in curves in (R_j, M_j)-space. An example of this is depicted in Figure 2.

3 Empirical Implications

To derive empirical implications, we consider those conditions necessary and sufficient for commercialization in start-up firms rather than established firms. Specifically, these are the conditions under which the unique equilibrium is that the TTO sells a license to a start-up firm.

Theorem 2 *Licensing to a start-up firm, instead of an established firm, is the equilibrium of this dynamic licensing and development game if and only if either:*
(i) $P_F(e^*_F(R^*_F, M^*_F), E^*_F(R^*_F, M^*_F)) < 0$ *or* $P_T(e^*_F(R^*_F, M^*_F), E^*_F(R^*_F, M^*_F)) < 0$, $P_S(e^*_S(R^*_S, M^*_S), E^*_S(R^*_S, M^*_S)) \geq 0$, *and* $P_T(e^*_S(R^*_S, M^*_S), E^*_S(R^*_S, M^*_S)) \geq 0$*; or*
(ii)$P_T(e^*_j(R^*_j, M^*_j), E^*_j(R^*_j, M^*_j)) > 0$ *and* $P_S(e^*_j(R^*_j, M^*_j), E^*_j(R^*_j, M^*_j)) \geq 0$ *for* $j = F, S$, *and* $P_T(e^*_S(R^*_S, M^*_S), E^*_S(R^*_S, M^*_S)) \geq P_T(e^*_F(R^*_F, M^*_F), E^*_F(R^*_F, M^*_F))$.

We think of the equilibrium with licensing to a start-up firm unfolding as follows. The TTO, given a disclosure, first considers licensing to an established firm. It determines the solution to (7) for $j = F$, the contract (R^*_F, M^*_F), conditional on equilibrium behavior by the inventor and firm in the development subgame. Licensing to this firm is not the equilibrium either if the firm cannot earn nonnegative profit, so it rejects the contract, or if the TTO cannot earn nonnegative expected net utility, so it does not even attempt to search for an established firm as a licensee. The TTO next considers shelving the invention, or returning it to the inventor, and providing minimal assistance in searching for investor to assist in a start-up firm. This yields the contract (R^*_S, M^*_S) that solves (7) for $j = S$, conditional on equilibrium behavior by the inventor and firm in the development subgame. Licensing to this firm is an equilibrium only if the firm can earn nonnegative profit, so it accepts the contract, and the TTO can earn nonnegative expected net utility, so it assists in the search for an investor for the start-up. Finally, this is also the equilibrium if a contract can be sold to either type of firm, and the TTO can earn nonnegative expected net utility in either case, but its payoff is greater with the optimal start-up contract.

If the TTO's utility cost of searching is the same for both types of firms, then we face the apparent conundrum that start-ups occur only if a start-up firm would earn greater (positive) expected profit, gross of any license payments, so that the TTO can earn greater net utility from licensing to a start-up under the optimal contract. Although this may seem unlikely, *a priori*, it is not impossible. Each firm's expected profit depends on the costs of its effort in development and its attempt to commercialize the invention. Established firms with in-house R&D and marketing staffs, and with given distribution channels, undoubtedly have a cost advantage in the development and commercialization of inventions that are closely related to their current product line. However, it is not obvious that they have such advantages with potential products that do not fit well in their existing product lines. These costs include the potential profits from foregone opportunities, and established firms typically have alternatives available that are more closely related to their current product lines, and so more profitable. Conversely, venture capitalists routinely deal with new products and processes that don't fit well in existing product lines, so they may well have cost advantages due to better access to and information about the technological expertise needed to develop and commercialize embryonic inventions. Thus, for inventions that are not closely related to product lines, or that are simply very embryonic, established firms may well have higher opportunity costs of development and commercialization.

Moreover, the expected profit of a start-up firm, gross of license payments, may be higher. In particular, if the equilibrium of the development subgame involves greater inventor and/or firm effort, then the probability of success, and so expected profit, is greater. This can happen, for example, if the start-up has a lower opportunity cost of development effort, due to either fewer profitable alternatives, or perhaps to some advantage in acquiring development expertise that an established firm does not have because the potential product is very different from its current product mix. Because inventor and firm effort are strategic complements, greater firm effort induces greater inventor effort, and thus a greater probability of success.

Finally, it is also possible that licensing to a start-up firm occurs, even if expected profit is same for both types of firms, simply because the TTO's opportunity cost of searching for an established firm as a licensee is greater. This is an assumption of our model, of course, but it is consistent with the stylized facts. TTOs tend to focus their limited time on finding established firms as licensees for their most promising inventions, while essentially ignoring the others, which then typically are commercialized only if the inventors make the lion's share of the effort to find investors to assist them in forming start-ups. Again, this is consistent with Shane's (2002) argument that licensing to start-ups is a second-best solution for TTOs.

We summarize the implications of the model for our empirical analysis in terms of characteristics of the inventor, the invention, and the TTO. Obviously this approach is somewhat arbitrary, but it facilitates the analysis and discussion. The primary characteristic of an inventor is his/her (perceived) quality. Higher quality inventors disclose inventions which, *ceteris paribus*, have higher probabilities of success and lower TTO utility costs of searching for an established firm as a licensee. Thus, because it is more costly to attempt to find a licensee for a "low-quality" disclosure, we expect to see more start-ups from low-quality sources.

The nature of the invention also is an important factor. For example, it is generally conceded that inventions that are the result of more applied research are “closer” to commercialization (i.e., in our model, they would need less additional development, if any). Such inventions would not only have higher probabilities of success, but also lower costs of the TTO’s search for an established firm as a licensee.

As is well known by now, TTOs are an important factor in university invention. First, they play a role as intermediaries between inventors and licensees, and as such have come to serve as guarantors of minimum quality levels (see Hoppe and Ozdenoren 2004 and Macho-Stadler, Perez-Castrillo, and Veugelers 2004). From this perspective, we expect fewer start-ups from more experienced and successful TTOs. Perhaps more importantly for our purposes, TTOs also rely on their experience and expertise in their search for firms to serve as partners in commercializing inventions. Thus, because it is more costly for an “inexperienced” TTO to find a licensee for any disclosure, we expect to see more start-ups from sources with less experience and/or less impressive track-records of commercialization.

Finally, another important factor in whether licensing occurs to a start-up or an established firm is the potential difference between the costs of additional development and the attempt to commercialize borne by these firms. As noted above, there may be such differences because these types of firms typically have different investment opportunities, and so different opportunity costs. For example, in considering the cost of additional development, an established firm has alternatives that typically include development of new products or processes that closely fit or complement its current product line, whereas investors who fund start-ups have alternatives that typically include a broader array of options, but lower expected rates of return. For this reason we conclude that financial market conditions may matter significantly in the creations of start-ups from university inventions.

4 Data

Data on start-up activity were gathered using the Association of University Technology Managers (AUTM) surveys for years 1993 - 2001. The sample for our analysis consists of the 61 universities that were respondents to the AUTM survey in each of these years. This sample includes 23 private universities and 43 universities with medical schools.

For each university i, we include a measure of faculty quality, $QUAL_i$, because we assume in our theoretical model that inventor quality affects both the probability of success and the utility cost of the TTO in searching for a firm to commercialize the invention. We used data from the 1993 National

Research Council's (NRC 1995) Survey of Ph.D. granting institutions. This is an imperfect proxy because it considers only the quality of Ph.D. granting departments, and because we must construct a measure for each university by forming a weighted average of the departmental quality scores, where the weights are faculty size.[5] The NRC rankings ranged from 0 to 5, where 5 indicates a distinguished department, so higher values of $QUAL_i$ correspond to higher quality. For reasons noted above, we expect a negative relationship between inventor quality and start-up activity.

We also include measures of TTO characteristics, because we assume in our model that TTO experience and expertise also affects the probability of success and the TTO's disutility of search. As noted above, less experienced TTOs may be less able to identify inventions with commercial potential and less able to find appropriate potential partners, so we expect more start-ups from less experienced TTOs. For each university i and each year t, we use the number of disclosures in the previous year, $DIS_{i,t-1}$, the TTO's age, $TTOAGE_{it}$, the number of licenses, LIS_{it}, the number of cumulative active licenses, ACT_{it}, the log of cumulative gross royalties, $LNCGROSS_{it}$, and the log of cumulative cashed-in-equity, $LNCCAINE_{it}$, to measure the relevant characteristics of the TTO. Those TTO's that have more inventions disclosed to them are more likely to be successful in commercialization simply because they have more new inventions in their portfolio for either established firms and start-ups. We lag this variable because we want it to represent the pool of disclosures available for commercialization. Similarly we believe that TTOs that are older, have more licenses overall, and have more active licenses also have more experience and expertise. We therefore expect a positive relationship between start-up firms, TTO age, licenses, cumulative active licenses, and cashed-in-equity.

We use four variables as proxies for the characteristics of the inventions, in terms of their commercial orientation. The presence of a medical school at a university suggests more applied inventions, and may suggest a more commercial orientation on the part of the faculty. It should be easier to interest established firms in these types of inventions, so we expect that the presence of a medical school may negatively be related to start-up activity. We use a dummy variable to measure the presence of a medical school ($MED_i = 1$ if medical school, 0 otherwise). We also use a dummy variable to denote whether the university is private or public ($PRIVATE_i = 1$ if private, 0 otherwise). Public universities receive substantial federal funding and may be restricted in pursuing risky technologies. Also, private schools

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[5] We thank Jerry Thursby for providing his NRC data.

may have more flexibility in research options and more ties to established firms, which leads us to expect private universities to generate fewer start-up firms. We also include the ratio of industrial research support to federal research support, $INDFED_{it}$, as an invention characteristic. We expect inventions from universities with greater industrial funding relative to federal funding to be more applied in nature, and so apparently more suitable for commercialization.

Finally, we include several measures of financial market and general business conditions. Previous literature on start-up activity has made little connection between university-industry technology transfer and general financial market conditions and sentiment. We obtained financial market data using the Chicago Center for Research in Securities Prices (CRSP). Interest rate data is compiled from the St. Louis Federal Reserve Database (FREDII) and the U.S. Department of Labor, Bureau of Labor Statistics. For each year t in the sample, we use the annual percentage change in the preceding year in the Dow Jones Industrial index, $PCHGDOW_{t-1}$, and the NASDAQ index, $PCHGNAS_{t-1}$, to measure relative business conditions. We also include the annual percentage change in the Federal Reserve's fed funds rate, $PCHGINT_t$. Each of these affect the ability of a start-up firm to raise capital, and so the costs of development effort and commercialization. Our model predicts that there should be fewer start-ups in less favorable financial conditions. We choose not to lag this variable to reflect the investors' use of some current business information.[6]

5 Empirical Analysis

We estimate two regression equations with our measures for the university inventor and invention, the TTO, and general business conditions. In the first regression, we use the number of start-ups at university i in year t as the dependent variable for the years 1994-2001. The universities in our sample generated 1983 start-ups, 61322 disclosures and 17713 licenses during this time period. In our second regression we use the number of cumulative startups at university i in year t as our dependent variable.[7] First, we regress the dependent variable on inventor quality, $QUAL_i$. Because we suspect there may be non-linearity in the effects of faculty quality, we also regress the dependent variables on its square, $QUALSQ_i$. We also regress

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[6] Alternative regression equations using the lagged percentage change in the fed funds rate had no meaningful impact on our results, and so are not reported here.

[7] Cumulative Start-ups includes AUTM data for start-ups generated from 1983 – 1993.

our dependent variables on our invention characteristics. We estimate an equation using private schools, $PRIVATE_i$, medical schools MED_i, industrial to federal research support ratio $INDFED_{it}$, as well as the log of the cumulative gross of royalty income as our explanatory variable. We estimate equations using our TTO characteristics, the age of the technology transfer office $TTOAGE_{it}$, lagged disclosures $DIS_{i,t-1}$, licenses LIS_{it}, active licenses ACT_{it} and the log of cumulative cashed-in-equity. Our last specification includes our variables measuring business conditions and market sentiment. We regress our dependent variables on the lagged annual percentage change in the fed funds rate, $PCHGINT_t$, the Dow Jones Industrial index, $PCHGDOW_{t-1}$, and the NASDAQ index, $PCHGNAS_{t-1}$. Finally, because we found autocorrelation in the dependant variables, we also regress these variables on their lagged values. The results of our preliminary regression analysis are in Tables 1 and 2. Table 1, column 1 is the primary regression model of interest.

In general, our results provide evidence that inventor quality has a negative impact on start-up activity. The coefficient for this variable is negative in all equations estimated, and significantly different from zero when start-ups are regressed on quality alone. This result stands in contrast to Di Gregoriao and Shane (2003), who find a positive relationship between start-up formation and faculty quality, as measured by the Gourman Report, for the period 1994-1998. However, it supports our assertion that more low-quality inventions are licensed to start-ups because it is easier to commercialize high-quality inventions with established firms. This is also consistent with the finding of Jensen, Thursby and Thursby (2003) that higher quality faculty disclose inventions at earlier stages of development, and the findings of Lach and Shankerman (2002) that higher quality faculty disclose more inventions and higher value inventions. Finally, the coefficient for the square of quality is always positive, though not always significant. This indicates that, as quality decreases, the number of start-ups increases at an increasing rate.

Lagged disclosures, and current licenses and cumulative active licenses, significantly predict start-up activity. TTO at universities that have generated more disclosures, and have more active licenses, are also more likely to be involved in licensing agreements with start-ups firms. This may occur for several reasons. First, "disclosure-rich" TTOs may have lower opportunity cost in finding a start-up licensee if they have many inventions with commercial potential to present to established and start-up firms. Second, these TTO's may gain experience from each disclosure reported to them. In turn, such TTO's may be more adept in identifying profitable inventions. Third, TTO's with many disclosures (and active licenses) may signal to established firms, start-ups and venture capitalists that they have a large invention portfolio worthy of attention. This may also be a signal to the established firms, start-ups and venture capitalists that faculty from this institution are "bright" and industry friendly. We find a positive relationship between licenses and start-up firm activity. The coefficient estimated for this variable is positive in each regression specification, but is never significantly different from zero.

The log of cumulative gross licensing royalties negatively affects start-up activity. Large gross licensing royalties indicate past TTO experience in licensing successful inventions, which our model predicts leads to not only higher estimates of the probability of success for current disclosures, but also lower TTO costs of searching for established firms as licensees. Such TTOs have less need to fall back on the second-best option of start-ups.

The log of cumulative cashed-in-equity was used to measure the past success of the TTO, especially with regard to past start-ups, as equity is often used in these cases. This coefficient is positive, but not significantly different from zero, in any of our estimated equations. This provides some evidence that TTO's which accept equity as payments in the technology transfer process may also license technologies to more start-ups. Feldman, Feller, Bercovitz and Burton (2002) find an increase in the use of cashed-in-equity in licensing agreements involving startup firms and some established firms. They also note the rise in securities prices in the 1990's that may have contributed to TTO perceptions of equity deals.

We also find evidence that TTO age has a positive effect on start-up activity. In each regression specification TTO age is positive and significantly different from zero. The older the technology licensing office the more likely the TTO is to license an invention to a start-up firm. This is consistent with the results of Lach and Schankerman (2002), who find that disclosures and their average values increase with TTO age, and Franklin, Wright, and Lockett (2001), who find that older universities are more successful in launching new startups. Feldman Feller, Bercovitz and Burton (2002) find the greater the amount of experience with technology transfer, the more likely the university will accept equity-based technology transfer mechanisms. Older, experienced TTOs are more effective in commercializing inventions, in general. Thus, although increases in TTO age increase both the probability of success of a given disclosure and the cost of TTO search for an established firm as a partner in our theory, it appears that the former effect outweighs the latter in this data.

We find no evidence that the ratio of industrial to federal research support predicts start-up activity. This is perhaps not surprising as Jensen, Thursby and Thursby (2003) find this variable does not help to predict the stage of development at which inventions are disclosed. Following Di Gregoriao and Shane (2003), we also used the ratio of industrial support to total research support in an attempt to capture the applied nature of research, but found no significance with this variable either. However, the coefficient for medical schools is negative and significantly different from zero in each equation estimated. This indicates that universities with medical schools appear to generate less start-up activity, and supports our view that inventors from medical schools may be more commercially oriented, so it is easier to license their inventions to established firms. It is also consistent with the finding of Jensen, Thursby and Thursby (2003) that universities with higher fractions of their inventions from medical schools have more inventions disclosed at an early stage of development. The estimated coefficient for private schools is positive, but not significant. This may help to explain university variations in start-up firm activity. Shane and Stuart (2002) find that intellectual eminence is positively related to start-up activity.

We find little evidence that interest rate changes affect start-up activity. When we include interest rates in our benchmark equations the sign of the estimated coefficient is ambiguous. However when we regress this explanatory variable on start-ups alone the estimated coefficient is negative but not significantly different from zero. This lends some support to our view that economic indicators and overall business sentiment may affect start-up activity.

Our explanatory variables for market indicators did help to predict start-up activity. In model 1, these estimated coefficients on these variables are positive but not significantly different from zero. We expected a positive relationship between changes in market indices and start-up activity. When we regress these explanatory variables on start-ups alone, we also find evidence that they have a significant effect on start-up activity. In these estimated equations the coefficients for the percentage change in the NASDAQ and the percentage change in the Dow are positive and significantly different from zero. However, when we use cumulative start-ups as our dependent variable, these values all maintain the correct signs except $PCHDOW_t$ in our benchmark equation, but are not significantly different from zero in any estimated equation.

Table 2 shows an alternative estimation using the cumulative number of start-ups as the dependent variable. The results are very similar to those when using the annual number of start-ups as the dependent variable, with the exception for financial variables just noted, and are not discussed in full detail here.[8]

6 Conclusion

We have developed a theoretical model to explain why commercialization of university research occurs in start-up firms rather than established firms. Several empirical implications follow immediately from the theory. Essentially, we are more likely to observe commercialization of university inventions by start-up firms in situations in which start-ups are more likely to have a cost advantage in the development or commercialization, or in which the opportunity cost of TTOs in searching for an established firm as a partner is higher. We summarize these in terms of characteristics of the inventor, the TTO, and the invention, and financial market conditions. Generally, we expect more licensing to start-up firms for lower quality inventors, TTOs with less experience and/or expertise, less applied inventions, and more favorable financial market conditions for venture capitalists and other investors.

We tested the implications of the model in terms of characteristics of the inventor, the invention, and the TTO, and financial market conditions using AUTM data for 1993-2001 We estimated equations for both the annual number of start-ups per university and the cumulative number of start-ups in each year. Our results provide evidence that inventor quality has a negative impact on start-up activity. Universities with higher quality faculty may have less need to commercialize their inventions through start-ups. We also find some evidence that as quality decreases, the number of start-ups increases at an increasing rate. We also find that lagged disclosures, current licenses, cumulative active licenses, and the age of the TTO have significant, positive effects on start-up activity, but cumulative gross licensing royalties and the presence of a medical school negatively affect start-up activity. we find little evidence that interest rate changes affect start-up activity, but some evidence that changes in the Dow and NASDAQ indices positively affect start-up activity.

However, this paper is, in a real sense, a progress report. There are several extensions, generalizations, and additional tests we are planning. The theory could be extended and developed more with respect to commercialization by start-ups. Although start-ups often do pay (typically small) fixed fees, and commit to pay some royalties if the invention succeeds, it is perhaps

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[8] AUTM survey data includes start-up activity from the 1983 period to 1993. The dependent variable includes these years as 1993. Excluding this year did not significantly change the impact of our results.

more common for both inventors and universities to take equity positions in start-ups. The model could be modified to include such equity contracts in the case of start-ups. However, we emphasize that this will not change the general result in Theorem 2. All that will change is the explicit form of the expected payoffs in this branch of the game tree (to reflect the new type of contract). Nevertheless, this approach could help to clarify some of the explanatory variables that could be used in the empirical analysis.

In addition, this model of commercialization in start-ups does not distinguish between inventor effort in searching for an investor and effort in further development. Although we expect that both of these types of effort have a utility cost to the inventor, it is unlikely that effort in searching for an investor positively influence the probability that the invention is a commercial success. This can be easily remedied by adding a separate term for inventor disutility of investor search (analogous to that for TTO search), so the inventor faces a search or not decision after the invention is returned and before the start-up development subgame.

Similarly, there are other approaches we can take to analyzing the current data set. We plan to examine negative binomial and Poisson regressions. We also plan to examine alternative specifications of dependent variables, such as the ratio of start-ups to disclosures and the mean difference of start-ups.

Kortum and Lerner (2000) find that venture capital fund-raising effects patenting rates. Venture capitalists play a unique role in start-up activity. Future versions of this paper will include variables measuring venture capital disbursements in our sample period. If venture capital is a significant factor in patenting rates, then it may also help to explain start-up activity. University licensing, patenting and start-up activity should be related in some way to market conditions and availability of capital and credit. We also plan to use other measures of market performance that may be particularly relevant to venture capitalists, such as the number of IPOs, the number of IPOs in specific industries, and indices measuring the performance of specific industries.

7 References

Association of University Technology Managers, *1995, 1996, 1997, 1998, 2000,* and *2001, AUTM Licensing Surveys.*

Bercovitz, J., M. Feldman, I. Feller, and R. Burton, 2001, Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins, and Pennsylvania State

Universities, *Journal of Technology Transfer* 26, 21-35.

Di Gregoriao, D. and S. Shane, 2003, "Why Do Some Universities Generate More Start-ups Than Others?," *Research Policy* 32, 209-227.

Feldman, M., I. Feller, J. Bercovitz, and R. Burton, 2002, "Equity and Technology Transfer Strategies of American Research Universities," *Management Science* 48 , .

Henderson, Rebecca, Adam Jaffe and Trajtenberg, 1998, "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988," *Review of Economics and Statistics*, 119-127.

Hoppe, Heidrun C., and Emre Ozdenoren, 2004, Intermediation in Innovation: The role of Technology Transfer Offices," Mimeo, Universitat Hamburg.

Jensen, R., and M. Thursby, 2001, Proofs and Prototypes for Sale: The Licensing of University Inventions," *American Economic Review* 91, 240-259.

Jensen, R., J. Thursby, and M. Thursby, 2003, "The Disclosure and Licensing of University Inventions: 'The Best We Can Do With the S**t We Get To Work With," *International Journal of Industrial Organization 21*, 1271-1300.

Kortum, S. and S. Shane, 2000, "Assessing the Contribution of Venture Capital to Innovation," *Rand Journal of Economics* 31, 674-692.

Lach, S. and M. Shankerman, 2002, "Incentives and Inventive Activity in Universities," Mimeo, Hebrew University and London School of Economics.

Levin, S. and P. Stephan, 1991, "Research Productivity over the Life Cycle: Evidence for American Scientists," *American Economic Review 81, 114-132.*

Lewis, K.S., L.M. Jones, M.S. Anderson, D. Blumenthal, and E.G. Campbell, 2001, "Entrepreneurship, Secrecy, and Productivity: A Comparison of Clinical and Nonclinical Faculty," *Journal of Technology Transfer* 26, 233-245.

Macho-Stadler, I., D. Perez-Castrillo, and R. Veugelers, 2004, "Licensing of University Innovations: The Role of a Technology Transfer Office," Mimeo, Universitat Autonoma de Barcelona and Katholieke Universiteit Leuven.

Mowery, D., R. Nelson, B. Sampat and A. Ziedonis, 2001, "The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980," *Research Policy* 30, 99-119.

Mowery, D. and B. Sampat, 2001, "University Patents and Patent Policy Debates in the USA, 1925-1980," *Industrial and Corporate Change* 10, 781-814.

Nelson, R. “What is Private and What is Public about Technology?” 1989, *Science, Technology and Human Values* 14(3), 229-241.

Owen-Smith, J. and W.W. Powell, 2001, To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer, *Journal of Technology Transfer* 26, 99-114.

Shane, S., 2000, “Prior Knowledge and the Discovery of Entrepreneurial Opportunities,” *Organization Science* 11, 448-469.

Shane, S., 2001, “Technological Opportunities and New Firm Creation,” *Management Science* 47, 204-220.

Shane, S., 2002, “Selling University Technology,” *Management Science* 48, 122-137.

Shane, S. and T. Stuart, 2002, “Organizational Endowments and the Performance of University Start-ups,” *Management Science* 48, .

Siegel, D., D. Waldman, and A. Link, 1999, Assessing the Impact of Organizational Practices on the Productivity of University Technology Transfer Offices: An Exploratory Study,” NBER Working Paper 7256.

Stephan, P., 1996, “The Economics of Science,” *Journal of Economic Literature* 34(3), 1199-1235.

Thursby, J., R. Jensen, and M.C. Thursby, 2001, Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities, *Journal of Technology Transfer* 26, 59-72.

Thursby, J. and S. Kemp, 2002, Growth and Productive Efficiency of University Intellectual Property Licensing,” *Research Policy* 31, 109-124.

Thursby, J., and M.C. Thursby, 2002, “Who is Selling the Ivory Tower? Sources of Growth in University Licensing,” *Management Science 48(1), 90-104.*

Thursby, M.C., J. Thursby, and E. Dechaneaux, 2004, “Shirking, Shelving, and Risk-sharing: The Role of University License Contracts,” Mimeo, Georgia Institute of Technology.

Thursby, J., and M.C. Thursby, 2004, “Patterns of Research and Licensing Activity of Science and Engineering Faculty,” in Ehrenberg, R. and P. Stephan, eds., *Science and the University,* Madison: University of Wisconsin Press (forthcoming).

Table 1: OLS Regressions of Number of University Start-ups

Inventor Characteristics							
C	1.392	1.900	2.005	2.713	4.289**	0.811**	-0.348
	(2.44)	(2.175)	(2.126)	(2.122)	(2.157)	(0.172)	(0.490)
QUAL	-0.979	-0.943	-1.009	-1.348	-3.929**		
	(1.196)	(1.192)	(1.158)	(1.158)	(1.428)		
QUALSQ	0.197	0.187	0.201	0.257	1.037**		
	(0.198)	(0.197)	(0.188)	(0.188)	(0.228)		
TTO Characteristics							
TTOAGE	0.045**	0.046	0.046**	0.048**			
	(0.015)	(0.015)	(0.014)	(0.015)			
DIS(-1)	0.010**	0.010**	0.010**	0.010**			
	(0.003)	(0.002)	(0.002)	(0.002)			
LIS	0.015	0.014	0.015	0.014			
	(0.010)	(0.010)	(0.010)	(0.010)			
ACT	0.001	0.001	0.001	0.001			
	(0.002)	(0.002)	(0.002)	(0.002)			
LNCCAINE	0.007	0.012	0.012	0.007			
	(0.023)	(0.022)	(0.022)	(0.022)			
LNCGROSS	-0.067	-0.056	-0.057	-0.109			
	(0.108)	(0.106)	(0.106)	(0.105)			
Invention Characteristics							
MED	-0.744**	-0.772**	-0.761**				
	(0.322)	(0.320)	(0.316)				
PRIVATE	0.069	0.072					
	(0.307)	(0.306)					
INDFED	0.277	0.180	0.171	0.393			
	(0.815)	(0.804)	(0.802)	(0.803)			
Financial/Market Conditions							
PCHGINT	0.109					-0.234	0.262
	(0.725)					(0.315)	(0.372)
PCHGDOW(-1)	1.588						3.051**
	(3.2)						1.431
PCHGNAS(-1)	1.091						1.957**
	(1.141)						(0.796)
STP(-1)	0.438**	0.436**	0.438**	0.467**		0.820**	0.817**
	(0.059)	0.058	0.058	(0.057)		(0.035)	(0.035)
R-squared	0.759	0.758	0.758	0.753	0.251	0.580	0.588
Adjusted R-squared	0.747	0.748	0.748	0.745	0.249	0.579	0.583
Observations:	311	311	311	311	465	400	400

Key: $p \leq .10$; * $p < .05$; ** Standard Errors are in parentheses

Table 2: OLS Regressions of Cumulative Number of University Start-ups

Inventor Characteristics							
C	3.066	2.697	2.989	3.653*	21.316**	0.281	-0.207
	(2.492)	(2.229)	(2.179)	(2.164)	(11.850)	(0.186)	(0.442)
QUAL	-1.006	-0.957	-1.135	-1.427	-18.336**		
	(1.222)	(1.219)	(1.185)	(1.182)	7.859		
QUALSQ	0.184	0.169	0.206	0.253	5.330**		
	(0.202)	(0.201)	(0.192)	(0.191)	(1.256)		
TTO Characteristics							
TTOAGE	0.037**	0.038	0.038**	0.038**			
	(0.015)	(0.015)	(0.015)	(0.016)			
DIS(-1)	0.015**	0.015	0.014**	0.015**			
	(0.002)	(0.002)	(0.002)	(0.002)			
LIS	0.005	0.005	0.005	0.004			
	(0.010)	(0.010)	(0.010)	(0.010)			
ACT	0.003**	0.003	0.003**	0.003*			
	(0.002)	(0.002)	(0.002)	(0.002)			
LNCCAINE	-0.028	-0.021	-0.022	-0.030			
	(0.025)	(0.024)	(0.024)	0.023			
LNCGROSS	-0.128	-0.106	-0.109	(-0.156)			
	(0.111)	(0.109)	(0.109)	0.107			
Invention Characteristics							
MED	-0.640*	-0.684	-0.656**				
	(0.336)	(0.334)	(0.331)				
PRIVATE	0.193	0.199					
	(0.313)	(0.312)					
INDFED	0.149	0.044	0.018**	0.183			
	(0.835)	(0.824)	(0.822)	(0.822)			
Financial/Market Conditions							
PCHGINT	0.550					0.003	0.005
	(0.740)					(0.006)	(0.006)
PCHGDOW(-1)	-0.843						1.819
	(3.247)						(1.387)
PCHGNAS(-1)	0.558						0.570
	(1.160)						(0.695)
CSTP(-1)	1.058**	1.058	1.058**	1.064*		1.131**	1.130**
	(0.009)	(0.009)	(0.009)	(0.009)		(0.006)	(0.006)
R-squared	0.994	0.994	0.994	0.994	0.243741	0.986798	0.986845
Adjusted R-squared	0.994	0.994	0.994	0.994	0.240971	0.986743	0.986736
Observations	311	311	311	311	549	488	488

Key: *p* ≤ . 10; * p < .05; ** Standard Errors are in parentheses

Figure 1

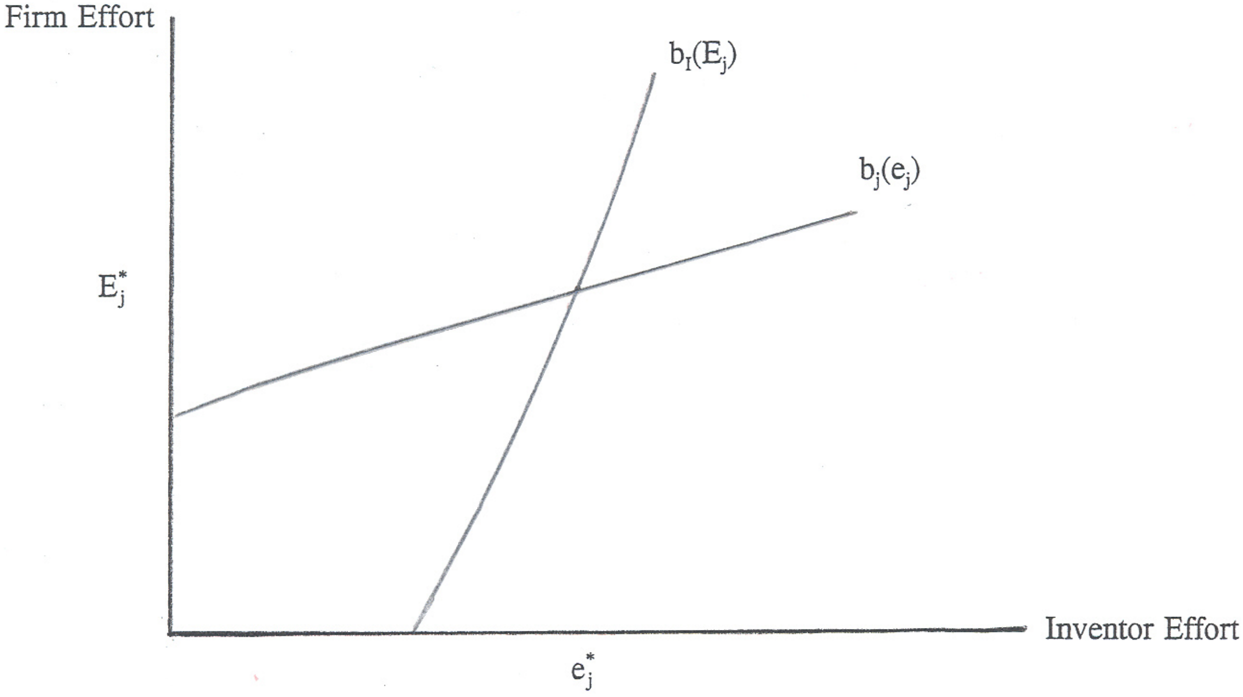

Figure 2