A Theory of University Startups and Local Employment*

Erika Färnstrand Damsgaard
Stockholm Research Institute for Industrial Economics

Richard Jensen
University of Notre Dame

October 18, 2010

Abstract

The Bayh-Dole Act of 1980 led to an explosion in the growth of technology transfer offices in U.S. universities, as well as a substantial increase in the commercialization of university inventions and resulting revenue. Most state universities have mission statements that require they assist in state/local economic development, and view their research parks and incubators as crucial to this aspect of their mission. This paper provides a theoretical analysis of university startups when local employment matters in the decision-making. Most universities also use royalties, which are a tax on output and, therefore, employment. The use of royalties, common in 84% of licenses, is therefore inconsistent with local employment objectives. We provide some empircal support for the hypothesis that the use of royalties has a negative effect on the total number of startups firms from a university's inventions, but not the number located in the university's home state.

* Very preliminary draft – please do not quote or cite without permission of the authors.

1 Introduction

The Bayh-Dole Act of 1980 led to an explosion in the growth of technology transfer offices in U.S. universities, as well as a substantial increase in the commercialization of university inventions and resulting revenue. Under this Act, 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. Annual surveys of the Association of University Technology Managers (AUTM) from 1991-2008 show that, on average, each university annually licensed 25 inventions to established firms, but only 3 inventions to startup firms. AUTM data also show that the number of licenses executed with established firms grew by 90%, while the number of licenses with startups grew by 105%. Given the embryonic nature of most university inventions, it is somewhat surprising that there has not been more commercialization via startups. It appears that both many universities and many state and local governments also hold this view, given the recent growth of incubators and research/innovation parks associated with universities. Indeed, it is difficult to find a major university that does not have one now.

Most state universities have mission statements that require they assist in state/local economic development, and view their research parks and incubators as crucial to this aspect of their mission. The mission statements of these research parks or incubators are generally multi-faceted, but most include statements to the effect that their goal is to facilitate the commercialization of university research via startup firms, and to support the attraction and growth of high-technology businesses in the area. Belenzon and Schankerman (2009) report that, in a survey of 86 U.S. universities, 77% of respondents stated that the promotion of local and regional economic development was either very important or moderately important as an objective of technology licensing. Although there has been a dramatic growth in research on university innovation and technology transfer, there has been very little theoretical work on optimal licensing of university technology to startups (Chukumba and Jensen 2006, Macho-Stadler, Perez-Castrillo, and Veugelers 2008, and Showalter 2010 are exceptions). Moreover, none of this literature focuses on local employment effects as an objective of any agent in the decision-making process.

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 university's technology transfer office (or office of technology licensing). Typically, the TTO makes an assessment of the disclosure and, if its commercial potential is great enough, then makes an effort to find an established firm willing to acquire a license for this new technology. Otherwise, it shelves the disclosure, in the sense that it makes no effort to seek a licensee. In these cases, sometimes the inventor will independently seek funding for a startup from a venture capitalist or angel investors. There are exceptions to this scenario, of course, especially at universities where there is a tradition of startups, such as MIT. Sometimes an inventor will even enter the disclosure process with funding for a startup available. Nevertheless, it is important to emphasize that universities own the patent rights to faculty inventions, so TTOs, operating as the university's agent in negotiating license agreements, have the final say on who acquires the license. This has led to situations in which faculty inventors and potential licensees have been upset with TTO decisions (Litan, Mitchell, and Reedy 2007).

This paper provides a theoretical analysis of university startups when employment as sell as license income matters in the decision-making. Although it is not evident why a particular inventor would devote much weight to local employment, the fact that universities at least pay lip service to it tends to imply that TTOs, who act as agents for their university, might place at least some weight on it in their decision-making, as indicated by the survey results in Belenzon and Schankerman (2009). One purpose of the paper is to determine optimal licensing contracts when employment is a university objective. Our main result is that when the TTO's objectives include employment as well as license income, the optimal royalty rate chosen by the TTO is lower than that which would be chosen otherwise. The reason is that royalties are essentially a tax on output or sales, and so reduce the output produced by the firm that licenses the invention. Lower output also results in lower levels of employment, at least as long as labor is not an inferior input in the firm's production process.

That the use of royalties is inefficient has long been known, of course. One explanation for their use in this context is that university inventions are typically so embryonic that some additional development is necessary for any chance of commercial success, and inventor involvement in that development effort is also necessary. Because faculty inventors typically suffer disutility from development, compared to their own research, they must be given some incentive to be involved in development. One way to do this is to offer the inventor a share of royalty income, which is paid only if the invention is a commercial success. This was first noted by Jensen and Thursby 2001, who also show that taking an equity position in the licensee is superior to using royalties for a university whose objective is maximization of the utility of its license income. This analysis herein shows that the use of royalties is "doubly" inefficient when the university's utility depends on employment as well as license income. This result is important in practice because universities generally rely heavily on the use of royalties (the survey of university TTOs in Jensen and Thursby 2001 reports that 84% of licenses executed included royalties), and some still have policies that forbid taking equity positions in startup firms. Some states have laws that prevent state universities from talking equity positions.

We briefly look at empirical considerations in terms of characteristics of the inventor, the TTO, and the invention, and financial market conditions. Our empirical analysis uses data from the Association of University Technology Managers surveys for 1991-2007, the 1993 National Research Council's Survey of Ph.D. Granting Institutions, and the National Venture Capital Association Yearbook 2007. The AUTM surveys report, for each university in each year, the total number of licenses to startups and the number of startups located in the university's home state. We estimate models for both of these measures of startups. We find some support for our theory in the sense that greater royalty payments per license make startups, and the resulting employment growth, less likely. This result is even more intriguing given that we also find that neither total not average royalty payments are correlated with startups located in the home state. Taken together, these results also tend to support the claim that there is a bias in support of local development in TTO licensing behavior. In addition, we find that the number of startups tends to be positively correlated with the availability of venture capital, but negatively correlated with changes in the NASDAQ index and the interest rate. This indicates that financial market conditions not only matter for the generation of startups, but that they are perhaos more likely when when finanical rates of return are falling (so alternative investments are less attractive).

2 Literature Review

These results contribute to a growing literature on university entrepreneurship and startups. Rothaermel, Agung, and Jiang (2007) provide a thorough review of the literature. Here we focus on the most closely related work.

The theoretical literature on university licensing predominantly focuses on the behavior of faculty in the research, disclosure, and commercial development of university inventions, and the behavior of technology transfer officers in licensing those inventions: Jensen and Thursby (2001), Jensen, Thursby, and Thursby (2003), Hoppe and Ozdenoren (2004), Chukumba and Jensen (2005), Macho-Stadler, Perez-Castrillo, and Veugelers (2007, 2009), Lach and Shankerman (2008), Decheneaux, Thursby, and Thursby (2009), Belenzon and Schankerman (2009), and Showalter (2010). None of these explicitly addresses the question of whether university inventions are licensed to startups or established firms. Two exceptions are and Showalter (2010), who explicitly develop game-theoretic models to explain when university technology is licensed to startup firms versus established firms. Only Belenzon and Schankerman consider local objectives of any type in the licensing decision, but there interest is focused on how faculty inventor compensation influences the TTO's decision of how much effort to focus on licensing in the national market viz a viz the local market. Their analysis ignores the licensees and the nature of the licensing contracts.

In a closely related literature, several other papers have asked why some inventions of an established firm's employees are commercialized through new startup firms rather than within the firm itself. There are four general explanations. One involves the well-known replacement effect (Arrow 1992). A successful innovation may cannibalize the profit of existing firms, so the incentive to innovate is greater for a startup that does not take the cannibalization effect into account. Similarly, if a failed attempt to commercialize can cause adverse spillover effects on an existing firm's profits from other products, then the incentive to innovate is greater both for a startup and an "unbranded" subsidiary of the existing firm (Wernerfelt 1988, Jensen 1992, and Gromb and Scharfstein

2002).[1] Established firms with production processes in place will have higher cost savings for inventions that are better fits for their current production and organization structures (Cassiman and Ueda 2005). Another explanation involves imperfections in the market for innovations. If firms can appropriate the returns to their employees' innovations when they reveal their ideas, then the employees should not reveal their ideas prior to starting-up their own firms (Anton and Yao 1995, Gans, Hsu and Stern 2002, and Gans and Stern 2003). Cassiman and Ueda (2005) observe that, if a firm can commercialize only a finite number of projects, then an established firm may bypass a current innovation, and commercialize it through a startup, in order to wait for another innovation in the future.

The empirical literature on university startups often focuses on case studies of specific universities that have provided exceptionally detailed data sets. For example, Shane studies startups based on inventions by MIT faculty. He shows that startups are more likely when inventors recognize business opportunities (Shane 2000) or technological opportunities (Shane 2001), and that licensing to inventor-startups is more likely when patents are ineffective at preventing information problems such as moral hazard and adverse selection (Shane 2002). He also finds that licenses to startups perform poorly compared to licenses to established firms, and concludes that licensing to startups is a second-best alternative for TTOs. Belenzon and Schankerman (2009) use their survey data to show that TTOs who indicate local development objectives are important tend to generate more local startups.

There are several general studies of startups using AUTM data. Di Gregoriao and Shane (2003) study startups from US universities using AUTM data for 1994 to 1998, finding a positive relationship between startup formation and faculty quality, as measured by the Gourman Report. O'Shea et al. (2005) also study startups created from U.S. universities using AUTM and NRC data for 1995 to 2001, finding positive relationships between startups and faculty quality (measured by NRC rankings), faculty size, federal funding for science and engineering, past success in startups, a high fraction of industry funding, and TTO size. Chukumba and Jensen (2005) also provide separate reduced form estimates of the number of startups initiated and the number of licenses using AUTM data from 1991 to 2002. They find positive correlation between licenses to both startups and established firms and faculty quality (though this effect is greater for engineering faculty quality), the age of the TTO, and the number of disclosures, although the size of the TTO did not have a significant effect on licensing to either type of firm. They also find that financial conditions matter, in that licenses to startups were negatively correlated to both the rate of return to venture capital and the interest rate, but positively correlated with the S&P 500. Jensen (2010) extends the analyses of startups by using data through 2004, measures of university faculty size in the life sciences and engineering, and time fixed effects, and by partitioning the data in new ways. He finds that

[1] Lewis and Yao (2001) and Motta and Roende (2002) argue that an established firm may grant its employees property rights to their inventions to improve their incentives.

startups are positively related to the quality of the engineering faculty, the levels of federal and industrial funding, disclosures, and the venture capital funding in the state where the university is located, but negatively related to the land-grant and private status of the university. Note that none of these studies uses royalty income or royalty income per license as an explanatory variable.

3 Theoretical Model

As noted in the introduction, under the Bayh-Dole Act, technology transfer officers are responsible for making good-faith efforts to commercialize university inventions. Universities are also required to give faculty inventors some of the revenue from license agreements. For simplicity we assume the TTO acts as an agent for the university, thus abstracting from any agency issues that might arise between the university administration and TTO. As noted above, given the disclosure of a potential invention, the TTO makes an assessment of the disclosure searches for a firm willing to acquire a license for this new technology. Although these license contracts are often quite complex, most commonly (see Jensen and Thursby 2001) they include a lump-sum fee m paid up front, and a royalty r paid on each unit of output produced if the invention is a success. As is well-known, university inventions are typically embryonic in the sense that their commercial potential is uncertain, their likelihood of success is small, and additional development effort by the firm with assistance from the inventor is usually required for any chance of success. Thus, if a firm acquires a license, there follows a development subgame in which it and the inventor devote effort to attempt to improve the commercial potential of the potential invention. The outcome of this game is a probability of success. Given this probability, the firm may expend the additional resources required to attempt to commercialization, after which it learns whether the invention is a success or not.

3.1 Production with a Successful Invention

Assume the invention is a success. Then the firm's profit from production, net of royalties, is $\Pi = [P(Q) - r]Q - \rho K - \omega L$, where $P(Q)$ is the demand function given output Q, and $P'(Q) < 0$ and $2P'(Q) + P''(Q)Q < 0$. If we also assume the production function is $Q = f(K, L)$, where the inputs are capital K and labor L and f is the strictly concave, and that ρ is the rental rate of capital and ω is the wage, then profit is

$$\Pi(K, L) = [P(f(K, L)) - r]f(K, L) - \rho K - \omega L. \tag{1}$$

Maximizing Π by choosing K and L implies the following first order necessary conditions for an interior maximum at (K^*, L^*):

$$\frac{\partial \Pi(K^*, L^*)}{\partial K} = [MR(Q^*) - r]\frac{\partial f(K^*, L^*)}{\partial K} - \rho = 0 \tag{2}$$

and

$$\frac{\partial \Pi(K^*, L^*)}{\partial L} = [MR(Q^*) - r]\frac{\partial f(K^*, L^*)}{\partial L} - \omega = 0, \tag{3}$$

where $Q^* = f(K^*, L^*)$ and $MR(Q^*) = P(Q^*) + P'(Q^*)Q^*$. As is well known, these equations implicitly define the profit-maximizing input demand functions $K^* = K^*(r, \rho, \omega)$ and $L^* = L^*(r, \rho, \omega)$.

Proposition 1 *(i)Higher royalty rates reduce the amount of labor employed by a licensee if labor is not an inferior input in the production process.*
(ii) Changes in the lump-sum fee have no effect on the amount of labor employed by a licensee.

Proof. Ordinary comparative statics analysis on (2) and (3) yields the following:

$$\frac{\partial L^*}{\partial r} = \frac{[MR(Q^*) - r]\left[\frac{\partial f}{\partial L}\frac{\partial^2 f}{\partial K^2} - \frac{\partial f}{\partial K}\frac{\partial^2 f}{\partial K \partial L}\right]}{\frac{\partial^2 \Pi(K,L)}{\partial K^2}\frac{\partial^2 \Pi(K,L)}{\partial L^2} - \left[\frac{\partial^2 \Pi(K,L)}{\partial K \partial L}\right]^2} = \frac{\partial f(K^*, L^*)}{\partial \omega}$$

and

$$\frac{\partial K^*}{\partial r} = \frac{[MR(Q^*) - r]\left[\frac{\partial f}{\partial K}\frac{\partial^2 f}{\partial L^2} - \frac{\partial f}{\partial L}\frac{\partial^2 f}{\partial K \partial L}\right]}{\frac{\partial^2 \Pi(K,L)}{\partial K^2}\frac{\partial^2 \Pi(K,L)}{\partial L^2} - \left[\frac{\partial^2 \Pi(K,L)}{\partial K \partial L}\right]^2} = \frac{\partial f(K^*, L^*)}{\partial \rho}.$$

That is, $\frac{\partial L^*}{\partial r} < 0$ if $\frac{\partial f(K^*,L^*)}{\partial \omega} < 0$, which means L is not an inferior input (see Bear 1965). Furthermore, because F does not enter (2) or (3), we have $\frac{\partial L^*}{\partial F} = 0$.
■

Recall when there are two or more inputs, one input may be inferior in the sense that a decrease in its price may not lead to an increase in either a firm's profit-maximizing input demand or its output. In this model, this latter effect is identical to that for the effect of an increase in the royalty rate on input demand, $\frac{\partial f(K^*,L^*)}{\partial \omega} = \frac{\partial L^*}{\partial r}$.

3.2 Development of the Invention Disclosure

After licensing, but before the invention is revealed to be a success, the firm and inventor devote effort to try to bring the invention to commercialization. This results in a probability of success $p(e, E)$ where e is inventor effort in development and E is firm effort. It is natural to assume that p is similar to a production function in the sense that it is increasing and strictly concave in (e, E), so these "inputs" have positive but diminishing marginal productivities, $\frac{\partial p}{\partial e} > 0 > \frac{\partial^2 p}{\partial e^2}$ and $\frac{\partial p}{\partial E} > 0 > \frac{\partial^2 p}{\partial E^2}$ for all (e, E). It is also reasonable to assume that these inputs are complements, so the marginal effect of additional inventor effort on the probability of success is greater when the firm provides greater levels of effort, or $\frac{\partial^2 p}{\partial e \partial E} > 0$. We finally assume each input is essential in that development cannot succeed unless the firm and inventor both supply effort, $p(0, E) = 0$ for all $E \geq 0$ and $p(e, 0) = 0$ for all $e \geq 0$.

A licensee's expected payoff in this development subgame also depends on (gross) profit from a successful invention, Π, its costs of development effort, $D_F(E)$, and the payments associated with the license contract, or

$$\Phi_F(e,E) = p(e,E)\{[P(Q^*) - r]Q^* - \rho K^* - \omega L^*\} - m - D_F(E). \quad (4)$$

We assume development costs are positive only if effort is expended, are increasing in effort, and are nondecreasing at the margin, $D_F(0) = 0$, and $D'_F(E) > 0$ and $D''_F(E) \geq 0$ for all $E \geq 0$.

Following Jensen and Thursby (2001), we assume the inventor's net utility is her utility from income, $U_I(Y)$, minus her disutility from effort in development, $D_I(e)$. We assume utility of income is positive and nondecreasing, $U'_I(Y) > 0 \geq U''_I(Y)$ (i.e., we allow for risk-neutrality as well as risk-aversion). We also assume the disutility of effort is positive only if effort is expended, $D_I(0) = 0$, and $D'_I(e) > 0$ and $D''_I(e) \geq 0$ for $e \geq 0$. Assuming that α is her share of license revenue, her expected payoff from the development subgame is

$$\Phi_I(e,E) = p(e,E)U_I(\alpha[rQ^* + m]) + [1 - p(e,E)]U_I(\alpha m) - D_I(e). \quad (5)$$

For tractability, we assume there are only two levels of effort, high and low, that the inventor and firm can choose, $e \in \{e_L, e_H\}$ and $E \in \{E_L, E_H\}$, where $e_L < e_H$ and $E_L < E_H$. Without loss of generality, we assume $e_L = E_L = 0$. The choices of the inventor and firm are then straightforward, and the equilibria follow immediately.

Proposition 2 *Development of the invention disclosure occurs in equilibrium if*

$$p(e_H, E_H)[P(Q^*)Q^* - rQ^* - \rho K^* - \omega L^*] \geq D_F(E_H) \quad (6)$$

and

$$p(e_H, E_H)[U_I(\alpha[rQ^* + m]) - U_I(\alpha m)] \geq D_I(e_H). \quad (7)$$

It is the unique equilibrium if (6) *and* (7) *hold with strictly in equality. Otherwise, no development is the unique equilibrium.*

Proof. First note that $p(0,E) = 0$ for $E \geq 0$ and $p(e,0) = 0$ for $e \geq 0$ imply that $\Phi_F(0,E_H) = -m - D_F(E_H) < \Phi_F(0,0) = -m$, and that $\Phi_I(e_H,0) = U_I(\alpha m) - D_I(e_H) < \Phi_I(0,0) = U_I(\alpha m)$. Thus, $E = 0$ is the firm's best reply to $e = 0$, and $e = 0$ is the inventor's best reply to $E = 0$, and so $(e^*, E^*) = (0,0)$ is a Nash equilibrium of this development game. Next, because $\Phi_F(e_H, E_H) = p(e_H,E_H)[(P(Q^*) - r)Q^* - \rho K^* - \omega L^*] - m - D_F(E_H) > \Phi_F(e_H, 0) = -m$, $E = E_H$ is the firm's best reply to $e = e_H$ only if (6) holds. Similarly, $e = e_H$ is the inventor's best reply to $E = E_H$ only if $\Phi_I(e_H,E_H) = p(e_H,E_H)U_I(\alpha[rQ^* + m]) + [1 - p(e_H,E_H)]U_I(\alpha m) - D_I(e_H) > \Phi_I(0,E_H) = U_I(\alpha m)$, or (7) holds. Q.E.D. ■

Given the embryonic nature of university invention disclosures, the probability of successful commercialization is zero if either the firm or the inventor refuse to devote effort to further development. However, if both devote effort to development, then the fundamental change is that they generate a positive probability of success, and thus positive expected payoffs from this success. The conditions in (6) and (7) merely state that this expected payoff exceeds the development cost for the firm and inventor, so development is an equilibrium. Conversely, the next result follows immediately when (7) does not hold.

Proposition 3 *Development does not occur in equilibrium unless the license contract involves a positive royalty rate.*

This is, of course, the result originally due to Jensen and Thursby (2001). If faculty inventors would rather continue to do research than divert time into commercial development, then they will not get involved in the additional development required unless their payoff is somehow tied to the commercial success of the invention. Charging a royalty per unit of output produced with a success is one way to do this.

3.3 TTO Licensing Decision

What the objectives of the university and/or TTO are, or should be, is largely still an open question. A variety of approaches have been taken, from the TTO maximizing a weighted average of administration and inventor utility, to maximizing its own utility subject to administrative constraints, to maximizing revenue or a weighted average of revenue from local and national sources (see the theoretical papers listed in Section 2 above). To focus sharply on how employment as an objective influences optimal licensing to firms, we include it as an argument in the TTO's utility function, $U_T(Y, L)$ where Y is university income from the license and L is employment generated by a successful invention. The TTO's expected payoff is then

$$\begin{aligned}\Phi_T(r, m) &= p(e_H, E_H)U_T((1-\alpha)(m + rQ^*), L^*) \\ &\quad + [1 - p(e_H, E_H)]U_T((1-\alpha)m, 0). \end{aligned} \tag{8}$$

The licensing game is a principal agent game in which the TTO is the principal and the inventor and firm are agents. The equilibrium is therefore the solution to the TTO's problem of choosing the royalty rate and up-front fee, r and m, to maximize its expected payoff (8) subject to the constraints that development occurs, (6) and (7), and that the firm earns nonnegative expected profit,

$$p(e_H, E_H)\{[P(Q^*) - r]Q^* - \rho K^* - \omega L^*\} - m - D_F(E_H) \geq 0. \tag{9}$$

Note that, for $m \geq 0$, (9) implies (6), so the TTO's problem is just to maximize (8) subject to (7) and (9).

With two constraints and two choice variables, the TTO may not have any options. For example, if we define $X_I = \{(r, m) : \Phi_I(e_H, E_H) \geq 0\}$ and $X_F = \{(r, m) : \Phi_F(e_H, E_H) \geq 0\}$, the sets of contracts (r, m) that satisfy the inventor's constraint and the firm's constraints (so the inventor will engage in development and the firm will accept the contract and engage in development). These sets may be empty; indeed, they will be if $D_I(e_H)$ and $D_F(E_H)$ are sufficiently large. Similarly, even if they are both nonempty, they may not intersect. Because we are interested in the case where the TTO can offer contracts that allow development, we assume X_I, X_F , and $X_I \cap X_F$ are each nonempty. And because the inventor's payoff is increasing in r and m (at least for low enough values of r), and the firm's payoff is decreasing in r and m, we generally expect an outcome in which the firm's constraint in (9) binds, but the inventor's constraint does not.

Proposition 4 *If the TTO executes a license contract (r^*, m^*) such that development occurs in equilibrium, and if labor is not an inferior input, then the optimal royalty rate r^* is less than the one which would be chosen if the TTO had no preference for generating employment.*

Proof. To conserve on notation, let $p_H = p(e_H, E_H)$, $Y_s = (1-\alpha)(m + rQ^*)$ and $Y_f = (1-\alpha)m$. First observe that royalty income is increasing in the royalty rate, at least for levels; that is, $\frac{\partial(rQ^*)}{\partial r} = Q^* + r\frac{\partial Q^*}{\partial r} > 0$ for $r = 0$. Next observe that $\frac{\partial \Phi_T(r,m)}{\partial r} = p_H \left[\frac{\partial U_T(Y_s,L^*)}{\partial Y}(1-\alpha)[Q^* + r\frac{\partial Q^*}{\partial r}] + \frac{\partial U_T(Y_s,L^*)}{\partial L}\frac{\partial L^*}{\partial r}\right]$. Thus, within the set $X_I \cap X_F$ where the TTO can freely choose the royalty rate, we expect it to increase r up to the point where $\frac{\partial \Phi_T(r,m)}{\partial r} = 0$, or r^* satisfies $\frac{\partial U_T(Y_s,L^*)}{\partial Y}(1-\alpha)[Q^* + r^*\frac{\partial Q^*}{\partial r}] + \frac{\partial U_T(Y_s,L^*)}{\partial L}\frac{\partial L^*}{\partial r} = 0$. If the TTO did not have employment as an objective, so $\frac{\partial U_T}{\partial L} = 0$, then it would choose the royalty r^{**} such that $\frac{\partial U_T(Y_s,L^*)}{\partial Y}(1-\alpha)[Q^* + r^{**}\frac{\partial Q^*}{\partial r}] = 0$. Because $\frac{\partial U_T(Y_s,L^*)}{\partial Y}(1-\alpha)[Q^* + r^*\frac{\partial Q^*}{\partial r}] + \frac{\partial U_T(Y_s,L^*)}{\partial L}\frac{\partial L^*}{\partial r} > \frac{\partial U_T(Y_s,L^*)}{\partial Y}(1-\alpha)[Q^* + r^*\frac{\partial Q^*}{\partial r}]$ if $\frac{\partial U_T}{\partial L} > 0$ and $\frac{\partial L^*}{\partial r} < 0$, it follows that $r^* < r^{**}$. ■

If the firm and inventor contraints allow the TTO to choose the (positive) royalty rate freely, then the resulting royalty will be lower the more the TTO places weight on employment as an objective of licensing. We provide an example in the next section to indicate the extent of this effect.

4 Example (in progress)

Consuder the following example. The production function is a Cobb-Douglas

$$f(K, L) = K^\beta L^{1-\beta}$$

where $\beta \in (0, 1)$ is a constant. As is well know, the problem of choosing K and L to minimize cost $C = \rho K + \omega L$ s.t. $Q = K^\alpha L^{1-\alpha}$ yields a total cost function of the form

$$C(Q) = kQ$$

where $k = \rho^\beta \omega^{1-\beta}(y^{\beta-1} + y^\beta)$ is a positive constant and $L^* = (\frac{\rho}{\omega}y)^\beta Q^*$. We also assume a linear demand function

$$P(Q) = B - bQ$$

where B and b are positive constants, and $B > k$. Profit is then

$$\Pi = (B - bQ - r - k)Q,$$

which is maximized at

$$Q^* = \frac{B - r - k}{2b},$$

so

$$\Pi^* = \frac{(B - r - k)^2}{4b}$$

and

$$L^* = (\frac{\rho}{\omega} y)^\beta \frac{(B - r - k)^2}{4b}.$$

5 Empirical Considerations (in progress)

In this section we provide an initial analysis of the relationship between startups and licensing behavior. These results are preliminary, but quite interesting. Data on commercialization of university inventions via startups were gathered from the AUTM surveys for fiscal years 1991 through 2008. These surveys provide data for each university in each year it answered the survey. The sample is an unbalanced panel of 515 universities, including 60 private universities, 56 land grant universities, and 128 universities with a medical school. Because startup firms generate new employment, we focus on measures of licensing to startup firms. We control for the use of royalties as well as other financial market indicators and measures of faculty and TTO size and quality. Table 1 shows the descriptive statistics for the all variables we consider in this sample. The average number of licenses to startups per university is 3.072 per year, and the average startups located in the home state per university is 1.876 per year.

We are primarily interested in whether the use of royalties has an effect on licensing to startup firms, as this is indicative of an effect of royalties on employment growth. For these estimations we use an equation of the form

$$Y_{it} = \alpha_{it} + \beta_1 X_{1i} + \beta_2 X_{2it} + \varepsilon_{it}, \tag{10}$$

where Y_{it} is the outcome of interest in university i in year t, X_{1i} is a vector of time-invariant variables, X_{2it} is a vector of time-varying variables, and ε_{it} is an error term. We consider two dependent variables, the number of licenses to startups, LIC_STRT_{it}, and the number of startups located in the home state, $STRT\_HS_{it}$ Following the theory, our independent variables include proxy measures of inventor and university characteristics, and financial market conditions.

AUTM data reports both license income from royalties and the number of licenses generating royalties, so we can use both total and average measures of royalties. Because the royalty data are skewed, we convert to logs. Specifically, as measures of a university's use of royalties we consider both the log of license income from royalties, $LNROYALTY_{it}$, and the log of license income from royalties per license generating royalties, $AVELNROYALTY_{it}$

Next, we include three measures of financial market and general business conditions: the level venture capital funding in the state in which each university is located in each fiscal year (also logged due to its highly skewed distribution), $LNVENTCAP_{it}$; the five-year rolling average of the rate of return on venture capital, $VC\_5YR\_RR_t$; the annual return on the technology-rich NASDAQ index, $NASDAQ_t$ (measured by the change); and the average annual interest rate (the rate on ten-year treasury bonds), IR_10_t. Venture capital funding measures the TTO's general ability to tap into venture capital funding, which affects the cost of search for a startup partner. This data is obtained from the National Venture Capital Association Yearbook 2008. If venture capital funding is more important for startup activity, we expect a positive relationship between venture capital and the number of startups and the startup ratio. Similarly, higher returns to venture capital may indicate a financial climate in which funding for startups is more likely. Return on the NASDAQ is one measure of the opportunity cost to potential licensees of investing in a university invention, so we anticipate it will be negatively related to startups and the startup ratios. The interest rate is the cost of capital, of course, which may not be very relevant to venture capitalists, who generally have funds on hand they are looking to invest. Interest rates therefore may have no significant effect on startup activity, but may make university inventions relatively more attractive if they are less capital intensive. Nevertheless, we have no prior on the relation between interest rates and licenses to established firms.

We also control for measures of inventor characteristics: the quality and size of the engineering faculty; $ENGSIZE_i$ and $ENGQUAL_i$; the quality and size of the natural sciences faculty, $SCISIZE_i$ and $SCIQUAL_i$; and the research funding received by the university from federal and industrial sources (which we log due to the highly skewed nature of their distributions across universities), $LNFEDFUND_{it}$ and $LNFEDFUND_{it}$. As with most previous studies, we use the data from the National Research Council's Survey of Ph.D. Granting Institutions (NRC 1995) to construct a quality measure for each university by computing the weighted average of the NRC scores for each department (where the weights are determined by faculty size). This measure is imperfect, both because it omits faculty without doctoral programs, and because it is now rather dated. Nevertheless, it is the best available quality measure at the moment. We control for quality and size in engineering and natural sciences because most inventions come from faculty in these disciplines, as opposed to those in the humanities or social sciences. The NRC rankings for each department in the survey ranged from 0 to 5, where 5 indicates a distinguished department, so higher values of any of the variables correspond to higher quality of the graduate faculty. Each of these measures are also somewhat coarse in the sense that they provide indications of the overall quality of the university's faculty. Nevertheless, we expect both licenses and startups to be positively correlated with the quality measures, though we have no prior on how they are related to the startup ratios with one exception. Firms generally support research intended to generate inventions that they intend to use themselves. Because this reduces the cost of searching for an established firm as a licensee, essentially to zero ex post, we expect industrial funding to be negatively related to the startups licensed ratio.

Finally, it is also common to control for TTO and university characteristics: the number of disclosures of potential inventions made by faculty to the TTO, INV_DIS_{it}; the size and age of the technology transfer office, $TTOSIZE_{it}$ and $TTOAGE_{it}$; and dummy variables to denote whether the university is private or public ($PRIVATE_i = 1$ if private, 0 otherwise), and whether it is a land grant institution ($LANDGRANT_i = 1$ if land grant institution, 0 otherwise).[2] More disclosures tend to allow TTOs to sell more licenses simply because they have more inventions in their portfolio. Larger TTO size may lead to more startups, but there is an endogeneity concern. TTOs may be larger simply because they have been more successful at licensing in the past, and so need more personnel to maintain current licenses, in which case the greater size does not translate into greater effort to license to startups. Conversely, older TTOs have more experience, and should be able to generate more licenses and more startups in general. Private universities may, in general, have higher quality faculty, in which case this dummy variable would be another proxy for faculty quality. However, unlike publicly funded universities, private universities are under no special pressure to be involved in local or regional economic development, so they may generally be less inclined to commercialize their inventions. This implies fewer licenses and startups, and possibly even lower startup ratios if commercialization has some stigma at privates. Land grant universities were created with a mandate to provide research and education more oriented to commercial application. This suggests that they may produce inventions that are applied, in the sense that they are less embryonic, so they are closer to commercialization and their commercial potential is more obvious. This might imply fewer startups.

Tables 2 and 3 show initial results for these regressions for licenses to startups and startups located in the home state. Each of these controls of time trends by using year fixed effects. As other studies have found, the number of startups tends to be positively correlated with the availability of venture capital, the quality of a university's engineers, the levels of external funding, and invention disclosures, but negatively correlated with changes in the NASDAQ index, the interest rate, and private and landgrant status. Total royalties are positively correlated with licenses to startups, but this is not surprising. Total royalties, like license income, serves as a proxy for past licensing success. High levels of past success indicate either a TTO that is experienced at finding licensees, or a university faculty which is attractive to potential licensees, or both. However, it is intriguing that the number of licenses to all startups is

[2] The omitted category in this case is those public institutions that do not have landgrant status, such as Indiana University and the Universities of Florida, Iowa, Michigan, Texas, Virginia, and Washington.

negatively correlated with average royalty revenue per license. We take this as support for our theory in the sense that greater royalty payments per license make startups, and the resulting employment growth, less likely. This result is even more intriguing given that the results in Table 3 indicate that neither total not average royalty payments are correlated with startups located in the home state. Taken together, these results also tend to support the claim that there is a bias in support of local development in TTO licensing behavior.

6 Concluding Remarks

In this paper we have determined optimal licensing contracts when employment is a university objective as well as license income. Our main result is that in this case, the optimal royalty rate chosen by the TTO is lower than that which would be chosen when employment is not an objective. The reason is that royalties are essentially a tax on output or sales, and so reduce the output produced by the firm that licenses the invention. Lower output also results in lower levels of employment, at least as long as labor is not an inferior input in the firm's production process.

That the use of royalties is inefficient has long been known, of course. Although they can be used to solve the mortal hazard problem that arises when an inventor suffers disutility from development, this analysis shows that their use is "doubly" inefficient when the university's utility depends on employment as well as license income. This result is important in practice because universities generally rely heavily on the use of royalties (the survey of university TTOs in Jensen and Thursby 2001 reports that 84% of licenses executed included royalties), and some still have policies that forbid taking equity positions in startup firms. Some states have laws that prevent state universities from talking equity positions. We find some support for our theory in the sense that greater royalty payments per license make startups, and the resulting employment growth, less likely, but haver no appaent effect on startups located in the home state, a policy that evidently conflicts with a desire for local employment growth via university inventions.

As a result, one important focus of future research should be to determine whether the use of equity in lieu of royalties can solve the moral hazard problem without restricting employment growth. Macho-Stadler, I., D. Perez-Castrillo, and R. Veugelers (2008) have provided a similar type of analysis for startups when license income is the only university objective. Extending this analysis should also include local/regional governments because they often help to fund, or at least provide tax abatement, to incubators and innovation parks.

7 References

Anton, J., D. Yao, 1995, Start-ups, Spin-offs, and Internal Innovations, *Journal of Law, Economics and Organization*, 11, p.362-378.

Arrow, K. 1962, Economic welfare and the allocation of resources for invention. In R. Nelson (Ed.), *The Rate and Direction of Inventive Activity*: 609-626. Princeton: Princeton University Press.

Association of University Technology Managers (1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 206, 2007), *AUTM Licensing Surveys*, Chicago, IL: Association of University Technology Managers.

Bear, D. V. T. "Inferior Inputs and the Theory of the Firm." *Journal of Political Economy*, 73 (1965), 287-289.

Belenzon, S. and M. Schankerman, 2009, "University Knowledge Transfer: Private Ownership, Incentives, and Local Development Objectives," J*ournal of Law and Economics*, 52, 111-144.

Cassiman, B., M. Ueda, 2006, Optimal Project Rejection and New Firm Start-ups, *Management Science*, 52, 262 -275.

Chukumba, C. and R. Jensen, 2005, "University Invention, Entrepreneurship, and Start-ups," NBER Working Paper 11475.

Dechaneaux E., M.C. Thursby, and J. Thursby, and 2009, "Shirking, Shelving, and Risk-sharing: The Role of University License Contracts," *International Journal of Industrial Organization*, 27 80-91.

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

Gans, Joshua S., David H. Hsu and Scott Stern, 2002, "When does start-up innovation spur the gale of creative destruction?" *Rand Journal of Economics*, Winter, 33(4): 571-586.

Gans, Joshua S., and Scott Stern, 2003, "The Product Market and the Market for Ideas: Commercialization Strategies for Technology Entrepreneurs," *Research Policy* 32: 333-350.

Gromb, D. and D. Scharfstein, 2002, "Entrepreneurship in Equilibrium," NBER Working Paper 9001.

Hellmann, T., 2002, "A Theory of Strategic Venture Investing," *Journal of Financial Economics*, 64 (2): 285-314.

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, 2005, "Intermediation in Innovation: The role of Technology Transfer Offices," *International Journal of Industrial Organization*, 25, 483-510.

Jensen, R., 1992, "Reputational Spillovers, Innovation, Licensing, and Entry," *International Journal of Industrial Organization*, 193-212.

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.

Jensen, R., 2010, "Startups Firms from Research in U.S. Universities Research," in Audretsch, D., S. Heblich, O. Falck, and A. Lederer (eds.), *Handbook of Research on Innovation and Entrepreneurship*, Edward Elgar Publishing.

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

Lach, S. and M. Shankerman, 2008, "Incentives and Inventive Activity in Universities," *RAND Journal of Economics*, 39, 403-433.

Lewis, T.R., and Dennis Yao, 2001, "Innovation, Knowledge Flow, and Worker Mobility," Wharton School Working Paper Series.

Litan, R., L. Mitchell, and E.J. Reedy, 2007, "Commercializing University Innovations: Alternative Approaches," *Innovation Policy and the Economy*, NBER.

Lowe, R. and A. Ziedonis, 2004, "Start-ups, Established Firms, and the Commercialization of University Inventions," mimeo.

Macho-Stadler, I., D. Perez-Castrillo, and R. Veugelers, 2007, "Licensing of University Innovations: The Role of a Technology Transfer Office," *International Journal of Industrial Organization*, 25, 483-510.

Macho-Stadler, I., D. Perez-Castrillo, and R. Veugelers, 2008, "Designing Optimal Contracts for University Spinoffs," *Journal of Economics and Management Strategy,"* 17, 185-218.

Motta, M. and T. Roende, 2002, "Trade Secret Laws, Labor Mobility, and Innovations," CEPR Discussion Paper 3615.

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.

National Venture Capital Association, 2009, National Venture Capital Association Yearbook, Arlington, VA: National Venture Capital Association.

O'Shea, R. P., T. J. Allen, A. Chevalier, F. Roche, 2005, "Entrepreneurial Orientation, Technology Transfer and Spinoff Performance of U.S. Universities," *Research Policy*, 34, 994-1009.

Rothaermel, F., S.D. Agung, and L. Jiang, 2007, "University Entrepreneurship: A Taxonomy of the Literature," *Industrial and Corporate Change*, 16, 154-170.

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.

Showalter, D., 2010, "University Inventions Licensed Through Startups," mimeo.

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 M.C. Thursby, (1998) "Are Faculty Critical? Their Role in University-Industry Licensing, *Contemporary Economic Policy 22*, 162-178.

Thursby, M.C., J. Thursby, and E. Dechaneaux, 2004, "Shirking, Shelving, and Risk-sharing: The Role of University License Contracts," mimeo.

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.

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.*

Wernerfelt, B., 1988, "Umbrella Branding as a Dignal of Product Quality: An Example of Signaling by Posting a Bond," *RAND Journal of Economics*, 19, 458-466.

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LIC_STRT	2563	3.072	4.860	0	60
STRT_HS	2333	1.876	2.993	0	49
LNROYALTY	2275	13.071	2.505	4.443	20.530
AVELNROYALTY	1636	1.602	2.057	0.033	12.975
NASDAQ	4067	10.293	33.902	-68.18	84.3
LNVENTCAP	5784	18.634	3.920	0.001	24.474
VC_5YR_RR	3848	16.447	15.722	-6.5	48.2
IR_10	3848	5.461	1.102	4.01	7.86
LANDGRANT	2677	0.306	0.461	0	1
PRIVATE	2979	0.291	0.454	0	1
SCISIZE	2450	240.037	322.544	9	3225
SCIQUALITY	2450	2.891	0.779	1.036	4.746
ENGSIZE	1705	100.137	86.126	7	423
ENGQUALITY	1705	2.761	0.829	1.008	4.631
TTOSIZE	3177	3.984	5.674	0	95
TTOAGE	3337	13.601	11.221	0	83
LNFEDFND	3243	17.789	1.346	9.867	21.616
LNINDFND	3176	15.689	1.411	4.663	19.709
INV_DIS	3340	71.707	100.471	0	1497

Table 2: Negative Binomial Regressions for Number of Licenses Executed to Startup Firms

LIC_STRT		LIC_STRT	
LNROYALTY	0.054***	AVELNROYALTY	-0.112***
	(0.017)		(0.031)
NASDAQ	-0.002**	NASDAQ	0.000
	(0.001)		(0.002)
LNVENTCAP	0.023*	LNVENTCAP	0.014
	(0.013)		(0.015)
VC_5YR_RR	0.007**	VC_5YR_RR	-0.011***
	(0.003)		(0.004)
IR_10	-0.326***	IR_10	0.153
	(0.095)		(0.107)
LANDGRANT	-0.106*	LANDGRANT	-0.152**
	(0.064)		(0.077)
PRIVATE	-0.304***	PRIVATE	-0.351***
	(0.078)		(0.094)
SCISIZE	-1.86E-04	SCISIZE	-4.46E-04**
	(1.60E-04)		(2.16E-04)
SCIQUALITY	0.011	SCIQUALITY	0.088
	(0.096)		(0.112)
ENGSIZE	-0.001	ENGSIZE	0.000
	(0.001)		(0.001)
ENGQUALITY	0.367***	ENGQUALITY	0.347***
	(0.089)		(0.104)
TTOSIZE	-0.030***	TTOSIZE	-0.014
	(0.009)		(0.011)
TTOAGE	0.004	TTOAGE	-0.002
	(0.002)		(0.003)
LNFEDFND	0.199***	LNFEDFND	0.109*
	(0.055)		(0.064)
LNINDFND	0.067**	LNINDFND	0.056
	(0.034)		(0.037)
INV_DIS	0.003***	INV_DIS	0.003***
	(0.001)		(0.001)
N	925		619
PSEUDO R^2	0.13		0.12

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10

Table 3: Negative Binomial Regressions for the Number of Startups Located in the Home State

STRT_HS		STRT_HS	
LNROYALTY	0.015	AVELNROYALTY	-0.027
	(0.017)		(0.031)
NASDAQ	-0.003**	NASDAQ	-0.002
	(0.001)		(0.002)
LNVENTCAP	0.036**	LNVENTCAP	0.020
	(0.015)		(0.016)
VC_5YR_RR	0.005	VC_5YR_RR	-0.006*
	(0.004)		(0.003)
IR_10	-0.220**	IR_10	0.119
	(0.107)		(0.101)
LANDGRANT	-0.174***	LANDGRANT	-0.215***
	(0.065)		(0.074)
PRIVATE	-0.342***	PRIVATE	-0.300***
	(0.081)		(0.092)
SCISIZE	-4.16E-04***	SCISIZE	-5.16E-04***
	(1.24E-04)		(1.51E-04)
SCIQUALITY	0.042	SCIQUALITY	0.017
	(0.095)		(0.104)
ENGSIZE	0.001	ENGSIZE	0.001**
	(0.001)		(0.001)
ENGQUALITY	0.232***	ENGQUALITY	0.237
	(0.090)		(0.101)
TTOSIZE	-0.011	TTOSIZE	-0.006
	(0.008)		(0.008)
TTOAGE	0.004*	TTOAGE	0.002
	(0.002)		(0.003)
LNFEDFND	0.145**	LNFEDFND	0.148**
	(0.058)		(0.066)
LNINDFND	0.070**	LNINDFND	0.046
	(0.035)		(0.037)
INV_DIS	0.003***	INV_DIS	0.003***
	(0.000)		(0.000)
N	844		609
PSEUDO R^2	0.15		0.15

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10