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Three essays on licensing university inventions

A dissertation submitted in partial satisfaction of the requirements for the degree  
Doctor in Philosophy

in

Economics

by

Radu Munteanu

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2007



The Dissertation of Radu Munteanu is approved, and it is  
acceptable in quality and form for publication on microfilm:

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Chair

University of California, San Diego

2007

## DEDICATION

I dedicate all my work and achievements to my late father, Stefan, my mother Ecaterina and my beautiful and funny son, Rowan Edmund. My grandparents are also recognized here for all their efforts and love.

I would like to thank them from the bottom of my heart for their love, patience, understanding and for providing me with a sense of being part of a great family. They gave me guidance when things seemed difficult, and so I succeeded.

## TABLE OF CONTENTS

Signature Page .....	iii
Dedication Page .....	iv
Table of Contents .....	v
List of Tables .....	vi
List of Graphs .....	vii
Acknowledgements .....	viii
Vita .....	ix
Abstract .....	x
Chapter 1.University research and technology transfer. Analyzing the quality of inventions .....	1
Chapter 2.Quality and beliefs in the market for university inventions.....	27
Chapter 3. Stage of development and licensing university inventions.....	42

## LIST OF TABLES

Table 1, Chapter 1. Descriptive statistics of the main variables.....	19
Table 2, Chapter 1. Total licenses/case and secrecies.....	20
Table 3, Chapter 1. Mean value of the main variables by department.....	21
Table 4, Chapter 1. Probit results for the Secrecy and Licensing processes.....	22
Table 5, Chapter 1. Duration model results for the events of first secrecy and license.....	23
Table 6, Chapter 1. Probit results of the secrecy process (with the experience variable).....	24
Table 1, Chapter 3. Descriptive statistics.....	57
Table 2.A, Chapter 3. Multinomial logit results for licensing.....	58
Table 2.B, Chapter 3 Multinomial logit results for patenting.....	59
Table 2.C, Chapter3. Multinomial logit results for royalty generation.....	60
Table 3, Chapter 3. Duration model results for the events of first license and first royalties.....	61
Table 4, Chapter 3. Summary of the test statistics for the multinomial analysis.....	62

## LIST OF GRAPHS

Graph 1, Chapter 1. Data set construction by stages of elimination.....	15
Graph 2, Chapter 1. Hazard function for the first secrecy.....	25
Graph 1, Chapter 3. Distribution of inventions by stage of development and licensing outcome.....	48
Graph 2, Chapter 3. Distribution of inventions by stage of development and patenting outcome.....	49
Graph 3, Chapter 3. Distribution of inventions by stage of development and positive royalties.....	50



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## VITA

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## ABSTRACT OF THE DISERTATION

Three Essays on licensing university inventions

by

Radu Munteanu

Doctor in Philosophy in Economics

University of California, San Diego, 2007

Professor, Michael Noel, Chair

My thesis analyzes the process of licensing university inventions by start-up and established firms. In particular, the licensing procedure involves the use of secrecyes, which are confidential agreements used by firms to learn about the quality of invention. My first two chapters of the thesis describe the quality characteristics of the secrecy agreements and analyze the efficiency implications of the secrecy device. In my last chapter, I describe the differences in licensing behavior between start-up and established firms with respect to the invention's stages of development.

I use a unique data set based on licensing activity at University of California, San Diego. I match this data set with the grant data obtained from the Office of Contracts and Grant, UCSD for the period 1986-2003.

I find that secrecy agreements can be used by firms as a contemporaneous measure of invention's quality, in their licensing decision. In addition, the secrecy device enhances weakly the efficiency of the licensing secrecy and the gains in welfare are proportional with the difference in production cost of established firm and the inventor.

In my last chapter I find that the odds ratio of licensing by start-ups relative to licensing by established firms is lower for more advanced stage inventions. This result can be used to analyze other complex issues regarding the licensing process, like efficiency and the role of asymmetric information in start-up formation.

## Chapter 1

# University research and technology transfer Analyzing the quality of inventions

### Abstract

In this chapter I show how an important quality measure for the university inventions, grants, affects the probability of taking a secrecy and a license. A secrecy is a confidential agreement used by the firms to learn about the quality of inventions prior to licensing.

The paper also introduces a new quality measure for the inventions which is based on the number of secrecy agreements previously executed on the invention.

I use two theoretical approaches to model the decision of taking a secrecy, namely sequentially and simultaneously. Both approaches provide predictions regarding how the quality variables affect the probability of taking a secrecy and a license.

Using data on licensing inventions at University of California, San Diego I test the predictions of the simultaneous model. The results show that the grants and other quality variables affect positively the probability of entering a secrecy and a license agreement. Another main result is that the number of past secrecy agreements can be used as a contemporaneous measure of invention's quality.

## **I. Introduction and motivation of the paper**

Licensing activity at universities has increased dramatically over the past decade. Due to the increasing amount of revenues generated by licensing, universities have designed policies that encourage the transfer of technology to firms. In addition, licensing has an important public policy component and thus the efficiency of the licensing process is a main objective for universities.

In this paper I show that inventions of higher quality are more likely to be licensed by firms. To measure the quality of inventions, I use variables like grants and other inventor's characteristics. The results show that the quality characteristics are positively related with the probability of taking a secrecy and a license. Secrecies are confidential agreements used by firms to learn more about the quality of inventions and determine the profitability of licensing.

When researching the quality of inventions, it is difficult for researchers (i.e. economists) to obtain the grants data. In this paper I introduce a new variable that responds to the grants variable and that can be easily obtained from the data reported by the licensing office. This new variable is "secrecies", and represents the total number of secrecy agreements executed on an invention prior to licensing. I show that the grants and other quality variables affect positively the probability of taking a secrecy, so even in the absence of information about grants firms can use secrecies to learn more about the quality of inventions.

In order to analyze the quality of inventions licensed by firms, past studies focused on the information provided by patents (number of classes, citations, and others). The main advantage of this new secrecy measure is that it is a contemporaneous measure of quality available from the early stages of invention's life. In contrast, traditional measures based on patent characteristics require a long time for the profile of that quality measure (e.g. citations) to develop.

Understanding the secrecy and licensing processes would provide more information on the quality of inventions and thus increase the efficiency in the market for university inventions. This information could also be important in understanding organizational differences in licensing behavior between different types of firm.

Analyzing the secrecy process, allows us to determine who takes the best available inventions in contemporaneous time (i.e. start-ups or established firms). The distinction between the two types of firms is

important in understanding the relationship between the nature of the licensee and the invention's quality and it has welfare implications. A detailed welfare analysis is provided in Munteanu (2007).

The licensing of university inventions has been the topic of various studies, but the secrecy process has not yet explored. Shane (2001b) discusses under what conditions a new technology is licensed through formation of a new firm. He finds that if the technology is newer, the patent protection in that field is stronger and complementary assets are less important, then it is more likely that a start-up firm licenses the technology.

Shane (2001a) finds empirically that the likelihood of a new firm to license a patented invention depends on the importance, radicalness and the scope of its patent. Lowe (2002) suggests that the informational asymmetry between the inventor and outside firm can raise the cost of licensing the technology<sup>1</sup>. If this is severe, inventors choose to found start-up firms to license their own technology in order to further develop them and reduce the asymmetry of information.

The main contribution of my paper is to introduce a new measure of quality: number of secretcies, which is useful in assessing the quality of a given invention in the absence of any patent data. Patent and citations data are only available after at least a few years, so a new contemporaneous measure of quality would give a more accurate view of quality in a short time period.

## II. Theory

The licensing process can be divided into three phases:

Phase 1: Production process for invention. Inventor's quality and other inputs enter a production function and the outcome is an invention with value  $v^*$ . Assume that  $v^*$  is drawn from a uniform distribution with support  $[0, \bar{v}]$ . For simplicity, I assume that  $v^*$  is constant across firms and time<sup>2</sup>.

Phase 2: Disclosure and marketing. The invention is disclosed in order to protect the property rights and start the marketing process for licensing the invention. During this process, potential licensees use secretcies to access technical details of the invention and to determine whether to license the invention. I assume that the potential licensees for a given invention are the following:

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<sup>1</sup> High costs occur as a result technological uncertainty and tacit knowledge.

<sup>2</sup> The model can be modified to incorporate an assumption of non-constant value of invention over time.

I) **One start-up firm.** This firm has a reservation value  $\underline{v}_{su} \in [0, \bar{v}]$ , and by assumption, knows the value  $v^*$ .

II) **Many established firms.** Each established firm  $i$  firm has a reservation value  $\underline{v}_i$ ,  $i \geq 1$ . For simplicity, I assume that  $\underline{v}_i = \underline{v}_j = \underline{v}_{estb}$ ,  $(\forall) i \neq j \neq su$ <sup>3</sup>. By assumption, these firms have a marketing and financial advantage over the start-up firm<sup>4</sup>.

The reservation values are common knowledge in my model. In addition, each firm has a firm-specific shock  $\varepsilon$  measuring the quality of the match with the invention. These shocks are i.i.d. across time and firms and uniformly distributed with support  $[-M, M]$ . Firms know their own  $\varepsilon$  but are not aware of other firm's shocks<sup>5</sup>. Established firms arrive at the inspection of invention in a randomly order<sup>6</sup>.

Phase 3. Licensing decision. A firm commits to a license and pays a fee.

### **Sequential Approach to Licensing**

I assume first that firms inspect a given invention sequentially and each learns the identity of all previous potential licensees. This assumption implies that firms can update their beliefs about the value of the invention. Later in the paper I consider a method of simultaneous inspection of inventions.

Under the sequential approach, the start-up moves first and decides whether to license the invention itself now or allow the university to shop the technology around to interested established firms. If the start-up declines the invention, then the first established firm has the opportunity to inspect the invention by entering a secrecy at a fixed cost 'c'. Having entered a secrecy, the first established firm learns  $v^*$  and decides whether it is profitable to license the invention. If the first established firm does not license the invention, the second established firm comes to inspect the invention and decides whether to license it and so on.

For simplicity I consider a 4 period model which captures the main intuition. In addition, I assume that all established firms are myopic and that start-up has the option of shopping around the technology,

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<sup>3</sup> The assumption of equal reservation values for all established firms is made for simplicity of the model and the heterogeneity among firms is introduced in the next paragraph through firm-specific shocks.

<sup>4</sup> Scott Shane (2002) provides a more complete analysis for the development of both assumptions.

<sup>5</sup> The distribution is common knowledge to all firms.

<sup>6</sup> The model can be extended to incorporate a matching parameter to order the arrival of firms.



especially if its reservation value  $\underline{v}_{su}$  is high. If  $\underline{v}_{su}$  is high, the start-up firm would prefer to wait for a more efficient established firm to license the invention since the royalties collected would be greater than the net value obtained from own licensing.

An established firm  $i$  enters a secrecy if  $E_i(v^*) + \varepsilon_i - c \geq \underline{v}_{estb}$ . If so, the firm learns  $v^*$  and licenses the invention if  $v^* + \varepsilon_i \geq \underline{v}_{estb}$ <sup>7</sup>. Established firm  $i$ 's expected value of  $v^*$  depends on the history of play and thus for the remainder of the paper I denote by  $E_i^k(v^*)$  established firm  $i$ 's expected value of  $v^*$  conditional on  $k$  secrets being taken previously.

Period 0: The start-up firm licenses the invention if  $v^* + \varepsilon_0 \geq \underline{v}_{su}$ , in which case the game ends. If it does not license the invention then the first established firm has the option to license it.

Period 1: Established firm 1 considers licensing the invention and forms an expectation about  $v^*$ :

$$E_1^0(v^* | \text{start-up did not license the invention}) = E(v^* | v^* + \varepsilon_0 \leq \underline{v}_{su}) = \frac{1}{2} \underline{v}_{su}.$$

Then established firm 1 checks if the following condition holds:

$$E_1^0(v^*) + \varepsilon_1 - c \geq \underline{v}_{estb} \quad (1)$$

If (1) holds, then the firm enters a secrecy. It learns  $v^*$  and determines whether:  $v^* + \varepsilon_1 \geq \underline{v}_{estb}$  (2)

If (2) holds, then the firm licenses the invention, otherwise it does not license it. If (1) does not hold, then established firm 1 does not take a secrecy and it does not license the invention.

Period 2: If the invention is not licensed by start-up or established firm 1, then established firm 2 considers licensing the invention and it updates its beliefs about  $v^*$ . There are two cases to be considered:

CASE A. If established firm 1 did not enter a secrecy, then:

$$E_2^0(v^* | (v^* + \varepsilon_0 \leq \underline{v}_{su}) \wedge (E_1(v^*) + \varepsilon_1 - c \leq \underline{v}_{estb})) = \frac{1}{2} \underline{v}_{su} \quad (8)$$

<sup>7</sup> The model assumes that there is a set of very low quality inventions which are never licensed even by the firm with the highest specific shock. Thus the upper bound  $M$  can never exceed  $\underline{v}_{estb}$ .

<sup>8</sup> In calculating the expected value of  $v^*$ , the only condition relevant for established firm 2 is the one in the first bracket. Then the result follows from the assumption of uniform distribution of  $v^*$ .

This expectation is a result of two jointly necessary conditions: start-up did not license the inventions and established firm 1 did not enter a secrecy. Since there is no previous secrecy executed, established firm 2 does not learn any additional information about the previous firms' specific shocks. As a result, its expected value is the same as established 1 firm's expected value.

CASE B. If established firm 1 entered a secrecy but did not license the invention, then:

$$E_2^1(v^* | (v^* + \varepsilon_0 \leq \underline{v}_{su}) \wedge (v^* + \varepsilon_1 \leq \underline{v}_{estb}) \wedge (E_1^0(v^*) + \varepsilon_1 - c \geq \underline{v}_{estb})) =$$

$$= \min\left\{ \frac{1}{2}\underline{v}_{su}, \frac{1}{4}(\underline{v}_{estb} - M - c) + \frac{1}{8}\underline{v}_{su} \right\} \quad (3)$$

This expectation is conditional on three jointly necessary conditions: the start-up did not license the invention, established firm 1 entered a secrecy and established firm 1 declined a license. The fact that a previous secrecy was executed and no license taken yields extra information about  $v^*$ . Notice that if the reservation value of the start-up firm is relatively higher than that of the established firms, then the second term in (3) is the smallest term<sup>9</sup>. In this case the established firm is relatively more efficient than the start-up (net of  $c$  and  $M$ ) and the fact that the established firm 1 entered and did not take a license changed the expected value of the established firm 2.

Having calculated the expected value of  $v^*$  in the case with no previous secrecies or one past secrecy, i.e.  $E_2^k(v^*)$  for  $k = 0$  or  $1$ , established firm 2 takes a secrecy if:

$$E_2^k(v^*) + \varepsilon_2 - c \geq \underline{v}_{estb} \quad (4)$$

If it does, then it checks the condition:  $v^* + \varepsilon_2 \geq \underline{v}_{estb}$  and licenses the invention if so. If not, the invention is not licensed by established firm 2.

Notice that  $E_2(v^*) \leq E_1(v^*)$ . In other words, as more secrecies are taken with no license executed, the conditional expected value of the invention goes down for the next potential licensee.

Period 3: If the invention is still not licensed, established firm 3 inspects the invention. There are four cases to be considered here:

CASE A. If the first two established firms did not enter secrecies, then:

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<sup>9</sup> The necessary condition is:  $\underline{v}_{su} \geq \frac{2}{3}(\underline{v}_{estb} - M - c)$

$$E_3^0[v^* | (v^* < \underline{v}_{su} - \varepsilon_{su}) \wedge (\varepsilon_1 < \underline{v}_{estb} + c - \frac{v_{su}}{2}) \wedge (\varepsilon_2 < \underline{v}_{estb} + c - \frac{v_{su}}{2})] = \frac{1}{2} \underline{v}_{su}^{10}. \quad (5)$$

Since no previous secrecies were executed established firm 3 does not learn any new information about  $v^*$  so its expectation remains the same as that of first established firm.

CASE B. If established firm 1 entered a secrecy and did not take a license and established firm 2 did not enter a secrecy, then:

$$\begin{aligned} E_3^1[v^* | (v^* < \underline{v}_{su} - \varepsilon_{su}) \wedge (\varepsilon_1 \geq \underline{v}_{estb} + c - \frac{v_{su}}{2}) \wedge (v^* < \underline{v}_{estb} - \varepsilon_1) \wedge (\varepsilon_2 < \underline{v}_{estb} + c - E_2^1(v^*))] = \\ = \min\left\{ \frac{1}{2} \underline{v}_{su}, \frac{1}{4} (\underline{v}_{estb} - M - c) + \frac{1}{8} \underline{v}_{su} \right\}. \end{aligned} \quad (6)$$

In this case the expectation of  $v^*$  is a result of four jointly necessary conditions: the start-up did not license the invention, established firm 1 enters a secrecy, established firm 1 did not license the invention and established firm 2 did not enter a secrecy. Since the established firm 2 did not enter a secrecy only the actions of the start-up and the established firm 1 are relevant for updating the expectation of  $v^*$  for the established firm 3. If the reservation value for the start-up is relatively higher than that of the established firm 1, then the second term of the 'min' function becomes the smallest term. Thus, the actions of the established firm 1 results in updating the expectation of the established firm 3.

Notice that the expected value of the invention for the established firm 3 is the same as in the case in which the established firm 1 entered a secrecy but did not license the invention.

CASE C. If the established firm 1 did not enter a secrecy and the established firm 2 entered a secrecy but did not license the invention, then:

$$\begin{aligned} E_3^1[v^* | (v^* < \underline{v}_{su} - \varepsilon_{su}) \wedge (\varepsilon_1 < \underline{v}_{estb} + c - \frac{v_{su}}{2}) \wedge (\varepsilon_2 \geq \underline{v}_{estb} + c - \frac{v_{su}}{2}) \wedge (v^* < \underline{v}_{estb} - \varepsilon_2)] = \\ = \min\left\{ \frac{1}{2} \underline{v}_{su}, \frac{1}{4} (\underline{v}_{estb} - M - c) + \frac{1}{8} \underline{v}_{su} \right\}. \end{aligned} \quad (7)$$

In calculating the expected value of  $v^*$  only the information provided by the start-up and the established firm 2 are relevant for the established firm 3.

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<sup>10</sup> In calculating the expected value of  $v^*$  for firm 3 only the first condition in the bracket is relevant and the results follows from the uniform distribution of  $v^*$ .

Generally, the expected value of  $v^*$  is the same after one secrecy, no matter which firm entered that secrecy.

CASE D. If the established firms 1 and 2 entered secrecies and did not license the invention, then:

$$\begin{aligned}
 E_3^2[v^* | (v^* < \underline{v}_{su} - \varepsilon_{su}) \wedge (\varepsilon_1 \geq \underline{v}_{estb} + c - \frac{v_{su}}{2}) \wedge (v^* < \underline{v}_{estb} - \varepsilon_1) \wedge (\varepsilon_2 \geq \underline{v}_{estb} + c - E_2^1(v^*)) \wedge (v^* < \underline{v}_{estb} - \varepsilon_2)] \\
 = \min\left\{ \frac{1}{2}\underline{v}_{su}, \frac{1}{4}(\underline{v}_{estb} - M - c) + \frac{1}{8}\underline{v}_{su}, \frac{5}{16}(\underline{v}_{estb} - M - c) + \frac{1}{32}\underline{v}_{su} \right\}. \quad (8)
 \end{aligned}$$

Since the established firms 1 and 2 entered secrecies and but did not license the invention, the established firm 3 learns more about the firm-specific shocks and  $v^*$ . To calculate  $E_3^k(v^* | \Omega)$ , the established firm 3 uses an information set  $\Omega$ . This information set contains the fact that the established firm 1 entered a secrecy and did not take a license ( $\varepsilon_1 \geq \underline{v}_{estb} + c - \frac{v_{su}}{2}$  and  $v^* < \underline{v}_{estb} - \varepsilon_1$ ) and that the established firm 2 entered a secrecy and did not take a license ( $\varepsilon_2 \geq \underline{v}_{estb} + c - E_2^1(v^*)$  and  $v^* < \underline{v}_{estb} - \varepsilon_2$ ).

If the reservation value of the established firms is much higher than  $\underline{v}_{su}$  then the only binding condition is the fact that the start-up did not license, so the expected value for the established firm 3 is similar to the case when no secrecies were entered and equal to  $\frac{1}{2}\underline{v}_{su}$ . If the reservation value of the established firms is much lower than  $\underline{v}_{su}$ , then only the information provided by the previous established firms is binding and is used in calculating the expected value. This expected value will be lower relative to the case when only the start-up firm declined the invention.

In order to understand better the updating process, it would be useful to consider 2 examples:

*Example 1.* In this case:  $\underline{v}_{su} = 20$ ,  $\underline{v}_{estb} = 5$ ,  $M = 2$ , and  $c = 1$ . In this case:  $E_1^0(v^*) = 10$ ,  $E_2^0(v^*) = 10$ ,  $E_2^1(v^*) = \min\{10, 3\} = 3$ ,  $E_3^0(v^*) = 10$ ,  $E_3^1(v^*) = \min\{10, 3\} = 3$  and  $E_3^2(v^*) = \min\{10, 3, 1.25\} = 1.25$ .

The established firms are able to update their beliefs about  $v^*$  if secrecies are executed and thus the expected values go down:  $E_1^0(v^*) > E_2^1(v^*) > E_3^2(v^*)$ . If no secrecies are previously signed, there is

no new information to update the beliefs about  $v^*$  and expected value stays the same for all firms:

$$E_1^0(v^*) = E_2^0(v^*) = E_3^0(v^*) = 10.$$

*Example 2.* Suppose that:  $\underline{v}_{su} = 8$ ,  $\underline{v}_{estb} = 6$ ,  $M = 2$  and  $c = 1$ . Then,  $E_1^0(v^*) = 4$ ,  $E_2^0(v^*) = 4$ ,  $E_2^1(v^*) = \min\{4, 1.75\} = 1.75$ ,  $E_3^0(v^*) = 4$ ,  $E_3^1(v^*) = \min\{4, 1.75\} = 1.75$ ,  $E_3^2(v^*) = \min\{4, 1.75, 1.08\} = 1.08$ .

Having calculated  $E_3^k(v^*)$  with  $k = 0, 1, 2$ , then established firm 3 decides whether to enter a secrecy by checking if:  $E_3(v^*) + \varepsilon_3 - c \geq \underline{v}_3$ . If so, then it licenses the invention if:  $v^* + \varepsilon_3 \geq \underline{v}_3$ . Otherwise the invention is declined and the game ends<sup>11</sup>.

By denoting with  $p_i$  the probability that established firm  $i$  takes a secrecy, we can write:

$$\begin{aligned} p_i &= \text{prob} [E_i^k(v^*) + \varepsilon_i - c \geq \underline{v}_i] = \text{prob} [\varepsilon_i \geq \underline{v}_i + c - E_i^k(v^*)] = 1 - \frac{M + c + \underline{v}_i - E_i^k(v^*)}{2M} = \\ &= \frac{M - c - \underline{v}_i + E_i^k(v^*)}{2M} \end{aligned} \quad (9)$$

**Prediction 1.** The probability of taking a secrecy is positively affected by the invention's expected value.

This result is useful in comparing the probability of taking a secrecy for two different inventions. Two inventions A and B with values  $v_A^*$  and  $v_B^*$  will be characterized by different expected values at every stage so we can then compare the probability of taking a secrecy inventions A and B at every stage.

**Prediction 2.** The expected value of a given invention goes down as more secretcies are executed and no

license is taken, i.e.  $E_1(v^*) \geq E_2(v^*) \geq E_3(v^*)$ <sup>12</sup>.

Other predictions implied by (6) are that the probability of taking a secrecy is decreasing in the cost of the secrecy and the firm's reservation value and increasing with the value of the upper bound of the firm's specific shocks<sup>13</sup>.

An important function of secretcies is to reduce the uncertainty about the quality of invention. For a given firm  $i$  the secrecy condition can be rewritten:

<sup>11</sup> The model can be extended to an infinite number of periods.

<sup>12</sup> Even though  $E(v^*)$  is weakly decreasing with the number of secretcies, there is still a positive probability that other secretcies or license will be taken if a firm has a high specific shock.

<sup>13</sup> This result depends on the assumption of risk-neutrality for firms.

$$E_i(v^*) \geq \underline{v}_{estb} + c - \varepsilon_i. \quad (10)$$

By adding and subtracting  $v^*$  from the LHS of (10) and then squaring both sides of the inequality we get:

$$v^{*2} + [v^* - E_i(v^*)]^2 - 2v^*[v^* - E_i(v^*)] \geq (\underline{v}_{estb} + c - \varepsilon_i)^2, \quad (11)$$

Using (11) and summing over all possible values of  $v^*$  we obtain:

$$\int_0^{\bar{v}} v^2 f(v) dv + \sigma_i^2 - 2 \int_0^{\bar{v}} [v^2 - vE_i(v^*)] f(v) dv \geq (\underline{v}_{estb} + c - \varepsilon_i)^2 \quad \text{or,}$$

$$\sigma_i^2 \geq (\underline{v}_{estb} + c - \varepsilon_i)^2 + \frac{\bar{v}^2}{3} - 2 \frac{1}{\bar{v}} \int_0^{\bar{v}} v E_i(v^*) dv \quad (12)$$

**Prediction 3.** The higher is the conditional variance of  $v^*$ , the more likely is that firms enter a secrecy.

If we denote by  $q_i$  the probability of license by firm  $i$  then:

$$q_i = \text{prob}[v^* + \varepsilon_i \geq \underline{v}_{estb} \mid \varepsilon_i \geq \underline{v}_{estb} + c - E_i(v^*)] = \int_A^M \int_{\underline{v}_{estb} - \varepsilon_i}^{\bar{v}} \frac{1}{v} \frac{1}{2M} dv d\varepsilon, \quad (13)$$

where  $A = \underline{v}_{estb} + c - E_i(v^*)$ . From (10) I obtain that:

$$q_i = \frac{1}{2M\bar{v}} [(\bar{v} - \underline{v}_{estb})(M - A) + \frac{M^2 - A^2}{2}] \quad (14)$$

Notice that if  $E(v^*)$  goes up, then the term “A” goes down and the probability of license goes up. Therefore, since  $E(v^*)$  is correlated with  $v^*$ , we can say that the quality of invention affects positively the likelihood of license.

**Prediction 4.** The quality of invention affects positively the likelihood of license.

In addition, the probability of license is positively affected by  $\bar{v}$  which is the upper bound of the value distribution.

Other predictions implied by (11) are that the probability of taking a license is affected by the distribution of the firm-specific shocks and is negatively affected by the firm’s reservation value.

### Simultaneous Approach to licensing

Alternatively, firms can inspect the invention simultaneously. This would be the case when firms do not have any information about past secrets taken by other firms and thus there is no updating mechanism for the expected value of the invention.

Established firm  $i$  enters a secrecy if:

$$E_i(v^*) + \varepsilon_i - c \geq \underline{v}_i, \quad (15)$$

where  $E_i(v^*) = \frac{\bar{v}}{2}$  is the unconditional expected value of  $v^*$ .

The total number of secrets entered will equal the number of firms for which firm-specific shocks exceed the threshold value of  $(\underline{v}_i + c - \frac{1}{2}\bar{v})$ , conditional on no license being taken previously.

The results of the simultaneous model are similar to the ones in the previous section, with the only difference being that  $E_i^k(v^*)$  equals  $\frac{\bar{v}}{2}$  for all firms. Then, the probability for firm  $i$  to take a secrecy is:

$$p_i = \text{prob} [E_i^k(v^*) + \varepsilon_i - c \geq \underline{v}_{estb}] = \text{prob} [\varepsilon_i \geq \underline{v}_{estb} + c - \frac{\bar{v}}{2}] = 1 - \frac{M + c + \underline{v}_{estb} - \frac{\bar{v}}{2}}{2M}. \text{ Thus,}$$

$$p_i = \frac{M - c - \underline{v}_{estb} + \frac{\bar{v}}{2}}{2M} \quad (16)$$

Notice that the probability of taking an extra secrecy is independent on the number of previous secrets.

**Prediction 1.** The quality of invention (through  $\bar{v}$ ) affects positively the likelihood of taking a secrecy.

The same result regarding the relationship between the probability of taking a secrecy and the uncertainty about  $v^*$  applies here.

The probability of licensing is:

$$q_i = \frac{1}{2M\bar{v}} [(\bar{v} - \underline{v}_{estb})(M - a) + \frac{M^2 - a^2}{2}], \quad (17)$$

where  $a = \underline{v}_{estb} + c - \frac{\bar{v}}{2}$ .

**Prediction 2.** The quality of invention (as given by  $\bar{v}$ ) affects positively the probability of licensing.

The results regarding the effect of the firm's specific shocks and reservation values on the probability of taking a license are similar to the sequential model.

As a conclusion, the simultaneous approach predicts that the probability of taking a secrecy or a license is positively related with the invention's quality.

There is an important difference between the two theoretical approaches described above. In the sequential model, firms use the information provided by the previous secrets to update their beliefs about the quality of invention. Thus, the sequential model is characterized by a learning process. In contrast, in the simultaneous model there is no learning by firms: the expected value of inventions stays the same for all firms regardless of the number of previous secrets executed.

In practice, it is important to know if the licensing process works under the assumption of sequential or simultaneous approach. Due to the confidentiality of the agreements, I assume that firms are not aware of previous secrets executed on the inventions<sup>14</sup>.

Thus, for my empirical analysis I use the predictions of the simultaneous model to test the following hypotheses:

Hypothesis 1. The quality of invention affects positively the probability of taking secrets.

Hypothesis 2. The quality of invention affects positively the probability of taking a license.

### III. Data Set

The data set is based on licensing activity at University of California, San Diego<sup>15</sup>. The two main sources of my data set are the grants reports and the licensing records.

The grants reports contain information on the grants amounts, name of the principal investigator, department and title of the project. While this data set is very detailed in many of its variables, it has two main limitations. First, it is only available starting with the year 1986, because previously the grants

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<sup>14</sup> This is also confirmed by the Technology Transfer Office at UC, San Diego.

<sup>15</sup> I am grateful to the TechTIPS and Office of Contract and Grant Administration at UCSD for providing me with the licensing and grant data.



information was collected by the main UC grants office and is not easily available<sup>16</sup>. The second limitation of the data is that the grants records only list one principal investigator for each of the project funded.

The second source of the data set is the licensing records of all inventions disclosed between 1971-2003 at UCSD campus. A record for a given invention has the following information: case number, name of inventor(s), invention title, disclosure date, patent and royalty information. In addition, it has a history of all agreements executed since disclosure, namely all past secrecies and licenses.

The data set covers the period 1979-2002 and contains 2092 entries. Each entry in the file does not represent individual inventions disclosed at UCSD. For each invention there is a *base case* and there are additional entries (there are on average 3 entries/case) below that base case. In addition, each invention has its own invention number and the additional entries (sub-cases) have the same invention number plus an extra numerical identifier.

The sequence numbers (entries) after the base cases refer to information regarding sub-cases, in particular new information regarding ongoing patenting activity. These additional entries allow the Technology Transfer Office to track patent actions. For example if it files for a provisional patent is applied it will have one sequence number, a full patent application will have another, a continuation-in-part application will have yet another sequence number and so on.

All relevant information on secrecies and licenses is listed with the base case and represent the entire licensing history (potential licenses take secrecies or licenses on for the base case, not on sub-cases).

Thus, the data set contains 1,200 base cases, i.e. 1,200 inventions. These base cases and inventions are equivalent in my paper<sup>17</sup>.

Due to the limitations on grants data, which are only available for 1986 onward, I excluded the inventions disclosed before 1986. In total, 131 inventions were eliminated from the original list so my data set has now 1,069 inventions.

In addition to inventions eliminated above, I excluded the inventions representing copyrightable works such as books, software code, graphics, photos, trademarks etc. Copyrightable works have a different

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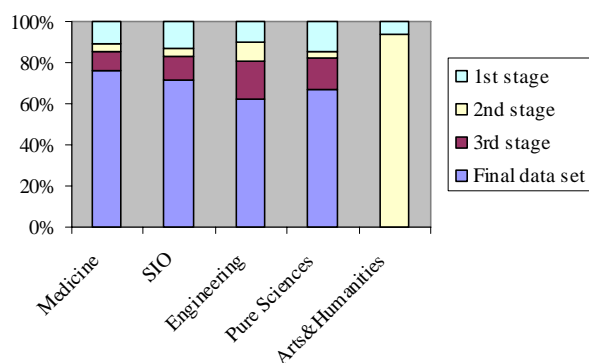
<sup>16</sup> I contacted the main UC Technology Office to obtain data on UCSD grants prior to 1986 but my attempts were not successful.

<sup>17</sup> For the purpose of my paper, base case and inventions are equivalent.

procedure for protecting the intellectual property and licensing. Thus, by eliminating them, I focus on a more homogeneous set of inventions with respect to patenting and licensing<sup>18</sup>. In total, a number of 244 copyrightable inventions were excluded from the original list after the second step, resulting in a data set of 825 inventions<sup>19</sup>.

Finally, I matched each invention with the corresponding grants<sup>20</sup>. I was able to match a total of 700 inventions. A graphical representation of the process of constructing my final data set is presented below:

Graph 1, Chapter1. Data set construction by stages of elimination



The main challenges encountered in obtaining the data set was the lack of a unified data recording system at UCSD and inability to collect complete information on inventions disclosed prior to 1986<sup>21</sup>.

The unit of analysis is an invention  $i$  disclosed at time  $T$ , where  $T \in [1986, 2003]$ . By denoting  $T_{j0}^i$  the year of PhD conferral for the inventor  $j$  who discloses the invention  $i$  at time  $T$ , then the following regressors are reported:

<sup>18</sup> TechTIPS provides the inventors of copyrightable works with a template statement, for the use of their works, should the inventors decide to freely share their work with the public. The statement affirmatively asserted copyrights for the regents of UC and disclaimed all liabilities and warranties for the university and the inventors.

<sup>19</sup> In the new data set, 60% of the inventions are in life science disciplines and 40% are from physical sciences and engineering.

<sup>20</sup> The inventions eliminated due to lack of grant data were mainly from 1999-2002 and had no securities or licenses. Since these inventions with no agreements are not included in my final data set, then the coefficients of the explanatory variables may be biased upward.

<sup>21</sup> In spite of these challenges, I received great support in collecting data from the TechTIPS Office and Contract Office. There is a great effort in these offices to centralize data in a detailed format.

**Grants** this variable equals  $\log(\sum_{t=T_{j0}^i}^T \frac{g_{jt}}{T-T_{j0}^i})$ , where  $g_{jt} \geq 0$  is the grant received by the inventor  $j$  in year  $t$ ,

such that  $t < T$  and  $t > \max\{1986, T_{j0}^i\}$ .

**Tenure** This variable equals 1 if the inventor  $j$  was tenured at the time  $T$  and is zero otherwise. An inventor was considered tenured if, by inspecting the information provided by her CV, she had the rank of associate professor or professor at time  $T$ .

**Publication** This variable equals  $\log(\frac{P_{jT}}{T-T_{j0}^i})$ , where  $p_{jT}$  is inventor  $j$ 's total number of publications

at time  $T$ . If the invention has multiple inventors, then the variable is calculated for the lead inventor.

**Time from PhD (T\_PhD)** This variable equals  $T-T_{j0}^i$ .

**Experience** This variable equals 1 if the inventor  $j$  has disclosed any invention  $k$  between  $[1986, T-1]$ ,  $k \neq i$ , and that invention was licensed by the year  $T-1$ .

**Department Dummies** The inventions are classified into one of the departments: Medicine, Neurology, Pathology, Pharmacology, Pure & Applied Sciences, BioMedical Engineering, Cancer Center, Biology, Chemistry & Biochemistry, Electrical & Computer Engineering, SIO. I aggregated these departments into five fields: medical, marine studies, electrical&engineering, chemistry&biochemistry and physical sciences.

The variables presented above, i.e. grants, tenure, experience, are proxy for the quality of the inventor. I assume that higher quality inventors produce higher quality inventions and therefore these variables are used in my empirical analysis as proxy for the quality of invention.

Table 1 presents the summary statistics of the main variables. Table 2 shows the distribution of inventions according to the total number of licenses and secretcies and a general description of the main variables by department is provided in Table 3.

## V. Empirical Results

The results describe how the quality variables for the inventions affect the likelihood of a secrecy or a license. I first estimate a probit model for the likelihood of taking a secrecy and a license.

The results of the probit estimation are given in Table 4. They show that the quality variables, grants and tenure, affect positively the likelihood of taking a secrecy<sup>22</sup>. An increase of 1% in the average grants amount received by the inventor since the PhD degree conferral increases the likelihood of taking a secrecy by 2.5%. Notice that the rate of publication affects negatively the likelihood of taking a secrecy which suggests that a higher rate of publication reveals more information about the inventor's research activity and reduces the uncertainty about the invention. As a result, firms are less likely to enter secrets.

The quality variables, the grants, tenure and publication history, affect positively the likelihood of taking a license<sup>23</sup>. These results are consistent with the theoretical predictions.

An interesting result is provided by the variable T\_PhD (time since PhD), which affects negatively the likelihood of taking a secrecy. One possible explanation is that more senior professors have a stronger publication record which would reduce the probability of taking a secrecy<sup>24</sup>.

In a robustness check, I estimate a hazard model to determine how the quality variables affect the probability of taking the first secrecy and the first license. The main advantage of the duration model is that it makes efficient use of data which is right-censored. For this model, I report the coefficients of the explanatory variables and the hazard ratios. A positive coefficient implies a higher likelihood of an event (i.e. taking a secrecy or a license) and a negative one implies a lower likelihood.

Graph 2 shows the Kaplan-Meier estimate of the survival function of for the event of the first secrecy. The hazard function decreases dramatically in the first 24 months, after which it flattens.

The estimation results of the duration analysis are presented in Table 5<sup>25</sup>. Notice that the quality variables affect positively the hazard of first secrecy. More specifically, an increase of 1% in the grants variable increases the probability of taking a secrecy by 3.9%. In addition, a high publication rate for the inventor reveals more information to the potential licensees and lowers the likelihood of the first secrecy.

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<sup>22</sup> A multinomial logit analysis with outcomes representing total number of secrets (0, 1, 2, 3, 4 and >5). The results do not show significant differences with respect to the quality characteristics.

<sup>23</sup> Analysis using ordered probit and logit estimation of the same event generates similar results.

<sup>24</sup> In another logit estimation in which the grants variable was divided in the following categories: *small*, *medium* or *large* the results show that, as compared to small grants, the medium and large grants increase the probability of taking a secrecy and a license. A similar analysis performed for the licensing event with three possible outcomes: 0, 1 and greater than 2, provide similar results.

<sup>25</sup> I use a Weibull baseline hazard function and the p-value is 0.47.

The results regarding the hazard of first license are similar to the probit estimation of the license event: all the quality variables affect positively the hazard of first license.

Table 6 shows the results of a probit estimation in which I added an extra variable “experience”. This variable is potentially endogenous to the secrecy and licensing processes thus the results should be interpreted with caution. These results are consistent with our previous conclusions: the quality characteristics affect positively the probability of taking a secrecy. In addition, past successful licensing experience increases the likelihood of a secrecy. More specifically, if the inventor has any past licensing experience then the probability of a secrecy goes up by 7.3%.

The probit results for the licensing process are similar to the previous estimations and show that the previous licensing experience increases the likelihood of a license by 9.9%.

The results are based on the assumption of the simultaneous approach, which predicts that the probability of taking a secrecy is positively related with the expected value of invention. In a sequential approach prior secrecies are negatively related with the expected value of invention. My estimation procedure omits the past secrecies as an explanatory variable, so if firms were using a sequential approach then my results would be biased upward.

## **VII. Conclusions and Direction of Future Research**

Testing the predictions of the simultaneous approach, the empirical results show that the grants variable and the other quality variables are positively related to the probability of taking a secrecy and a license. Because the secrecy variable responds positively to the grants variable (and other quality variables), then the number of past secrecies executed on an invention can be used as an early indicator of invention’s quality. The advantage of this quality indicator is that is easily available when other quality measures are hard to obtain (e.g. grants) or are not available yet (e.g. patent data). The new secrecy measure would provide researchers with more information about the quality of invention, thus reducing the asymmetry of information. This could also have positive effects on the efficiency of the licensing process.

The overall contribution of the paper is to provide a better understanding of the licensing process, with important implications from the public policy perspective.

Table 1, Chapter1. Descriptive Statistics of the Main Variables

Variable	Mean	Std. Dev	50%	75%	90%
SECRECY	1.99	3.14	1	3	6
LICENSE	0.55	0.78	0	1	1
GRANTS	262	445	191.7	270	410.6
TENURE	0.75	0.43	1	1	1
PUBLICATION	95	90	64	128	230
EXPERIENCE	0.60	0.48	1	1	1
T_PHD	14.6	10.09	14	21.3	31

Note: The GRANTS variable is expressed in thousands of dollars.

Table 2, Chapter1. Total Licenses/case and Secrecies

Total Licenses/case	# Secrecies												Total
	0	1	2	3	4	5	6	7	8	9	10	>11	
0	234	30	21	23	22	21	2	8	10	2	3	10	386
1	96	76	25	10	14	8	6	5	3	8	0	6	257
2	11	9	3	3	4	5	2	0	4	1	0	2	44
3	1	0	0	0	0	2	2	0	0	0	3	0	8
4	0	0	0	0	0	0	0	0	0	0	1	1	2
5	0	0	0	0	0	0	0	0	0	0	0	1	1
6	0	0	0	0	0	0	1	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	342	115	49	36	40	35	13	13	17	12	7	21	700

Table 3, Chapter1. Mean value of main variables by department

Department	Variable				
	SECR	LIC	Ten	Pub	Grants
Medicine	2.46	0.47	0.77	100	270,922
Neurology	1.83	0.62	0.91	183	178,149
Pathology	2.38	0.57	0.95	30	147,192
Pure&Applied Sciences	1.5	1	1	20	2,408,993
BioMedical Engineering	1.1	0.43	0.83	70	296,892
Cancer Center	1.13	0.24	0.59	56	234,634
Biology	2.63	0.63	0.75	73	233,581
Chemistry&Biochemistry	1.66	0.39	0.89	178	208,042
Electrical&Computer Engineering	2.04	0.36	0.75	63	252,254
Pediatrics	1.73	0.91	0.64	48	310,746
Physics	1.93	0.26	0.63	86	627,456
Pharmacology	1.97	0.95	0.90	125	302,022
SIO	1.60	0.55	0.68	135	354,565



Table 4, Chapter1. Probit Results for the Secrecy and Licensing processes.

Outcome	SECR		LIC	
Variable	Coeff	dy/dx	Coeff	dy/dx
Grants	0.083 (0.057)	0.025 (0.019)	0.121 (0.047)*	0.043 (0.017)*
Publication	-0.092 (0.077)	-0.025 (0.028)	0.017 (0.093)	0.007 (0.018)
Tenure	0.502 (0.231)**	0.161 (0.057)	0.194 (0.211)	0.083 (0.038)
T_PhD	-0.021 (0.007)*	-0.007 (0.003)	-0.03 (0.009)	-0.002 (0.004)
controls for dept	yes		yes	
Observations	700		700	
Log Likelihood	-267.31		-299.42	
LR for chi-squared test	331.29		351.91	
Pseudo R-squared	0.3714		0.3953	

Note: \* significance at 5%, \*\* significance at 10%.

The marginal effects are calculated at the means of the independent variables.

Table 5, Chapter1. Duration model results for the events of the first secrecy and first license

Outcome	SECR		LIC	
Variable	Coeff.	Hazard Ratio	Coeff.	Hazard Ratio
Grants	0.039 (0.019)**	1.037 (0.032)**	0.176 (0.053)*	1.109 (0.017)*
Publication	-0.021 (0.055)	0.986 (0.061)	0.026 (0.065)	1.024 (0.071)
Tenure	0.022 (0.018)	1.020 (0.023)	0.531 (0.211)*	1.682 (0.419)*
T_PhD	-0.011 (0.002)*	0.985 (0.009)*	-0.006 (0.005)	0.992 (0.007)
controls for dept.	yes		yes	
Observations	700		700	
Log Likelihood	-462.34		-521.54	
LR for chi-squared test	174.81*		149.98*	
Pseudo R-squared	0.2418		0.2511	

Note: \* significance at 5%, \*\* significance at 10%

Table 6, Chapter1. Probit results of the secrecy process (with the experience variable)

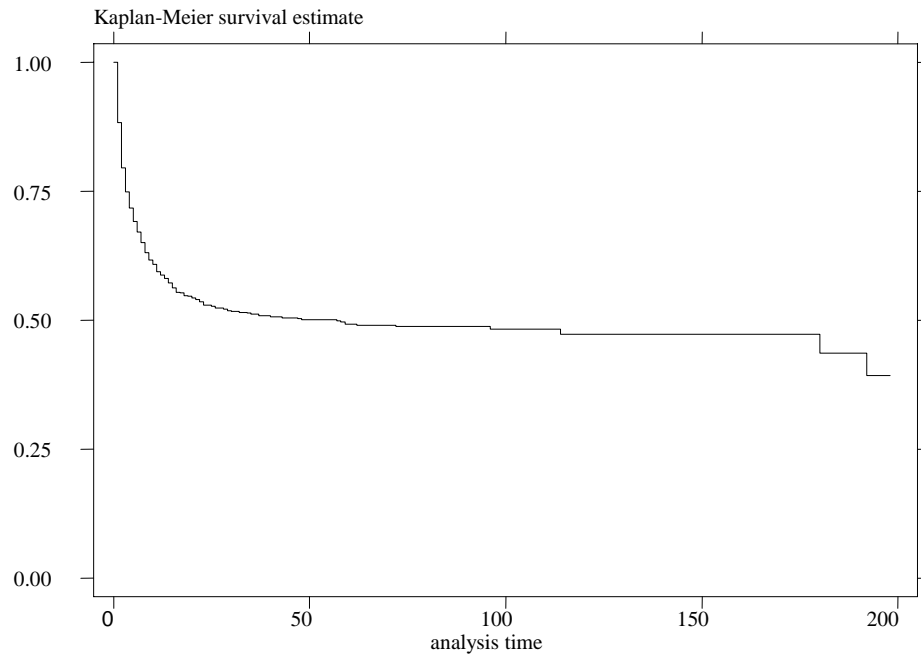
Outcome	SECR		LIC	
Variable	Coeff.	dy/dx	Coeff	dy/dx
Grants	0.121 (0.068)**	0.039 (0.005)**	0.109 (0.017)*	0.028 (0.003)*
Publication	-0.083 (0.101)	-0.021 (0.039)	-0.009 (0.044)	-0.018 (0.007)
Tenure	0.346 (0.095)**	0.221 (0.093)	0.145 (0.236)	0.043 (0.029)
Experience	0.096 (0.026)**	0.073 (0.026)**	0.126 (0.020)*	0.099 (0.015)*
T_PhD	-0.017 (0.019)	-0.005 (0.008)	-0.118 (0.009)	-0.003 (0.006)
controls for dept.	yes		yes	
Observations	700		700	
Log Likelihood	-395.23		-441.42	
LR for chi-squared test	405.47*		451.62*	
Pseudo R-squared	0.3987		0.3991	

Note: \* significance at 5%, \*\* significance at 10%

The marginal effects are calculated at the means of the independent variables.

Graph 2, Chapter1. Hazard function for the event of the first secrecy

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Note: the analysis time is in months.

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## Chapter 2

### Quality and beliefs in the market for university inventions

### Abstract

The paper analyzes the efficiency implications for the licensing process of university inventions when firms can use the secrecy device. Secrecy is a confidential agreement used by the firms to learn about the quality of inventions prior to licensing. I use a bargaining model with one-side private information to analyze the extent to which the *secrecy* device improves the efficiency of the licensing process.

The decision to enter a secrecy agreement is determined by the uncertainty about the underlying quality of inventions. The bargaining model assumes that the university/inventor has private information about the value of invention and that firms use secrecy as costly device to guarantee the quality of the invention.

The main results show that the secrecy device increases the efficiency of the licensing process and that the gains in efficiency are proportional with the difference between the established firm's cost of production and the inventor's cost of production.

## **I. Introduction and short literature review**

This paper analyzes the contribution of secrecy agreements to the efficiency of the licensing of university inventions by start-up and established firms. Secrecies are confidential agreements which can be used by firms to learn about the quality of the inventions. Asymmetry of information regarding the value of invention between firms and inventor plays an important role in licensing decision by start-up and established firms. The objective of the paper is to use a model of bilateral bargaining with adverse selection to analyze the extent to which the secrecy device affects the efficiency of the licensing mechanism. The main question addressed in this paper is the following: *Under what conditions does the secrecy device improve the efficiency of the licensing process and what is the gain in efficiency?* Using a bilateral bargaining model of licensing the paper analyzes the gains in the efficiency of licensing when firms use the secrecy device. My results show that the secrecy device increases the efficiency of the licensing mechanism and that the gains in efficiency are proportional with the difference in the cost of developing the invention for established and start-up firms.

Numerous empirical and theoretical studies on licensing activity at universities analyze the implications of the informational asymmetries for the efficiency of the licensing process. However, this is the first theoretical paper to describe the contribution of the secrecy device to the efficiency of the licensing process.

Samuelson (1984) argues that the presence of asymmetric information in bargaining may preclude the attainment of a mutually beneficial sale. Thus, understanding the role of the secrecy device in reducing the asymmetry of information in the licensing process is very important from a public policy perspective. Since the research activity at university is publicly funded, there is a great interest in licensing the inventions with the highest degree of efficiency.

In a survey study of licensing university inventions, Thursby & Thursby (2004) found that large proportions of the inventions disclosed at universities are in embryonic stages. These inventions require a large financial effort from the part of the licensees and thus it is important to understand the mechanism by which firms ensure the profitability of inventions. One device that firms can use to learn about the quality



of inventions is the *secrecy*, which allows firms to learn about the underlying quality and decide whether to license the invention.

Shane (2002) argues conceptually that licensing to a start-up is a "second best solution" because start-ups lack the necessary assets to bring the inventions to the commercialization stage. Established firms enjoy a comparative advantage in commercializing the inventions due to their have the marketing skills, complementary assets and production capabilities. Lowe (2003) argues conceptually that start-ups emerge as a vehicle of developing the inventions because the asymmetry of information raises the cost of licensing for established firms.

The existing studies suggest that the asymmetry of information introduces inefficiency in the licensing process by start-up and established firms. The main contribution of my paper is to provide a formal analysis of the licensing process with a secrecy device and determine the efficiency when firms use this device. The paper also includes a quantitative description of the efficiency gains which are due to the use of secrecy device, which is not performed in other studies.

In my paper I use a model of bilateral bargaining with adverse selection similar to Samuelson and Bazerman' Acquiring a Company Game (1985). In "Acquiring a Company Game" an acquirer is considering making an offer to buy out a target firm. The target firm is more valuable under the acquirer management than under the present ownership but the acquirer does not know the target's real value.

I extend this model by allowing the established firm to make an offer for an invention in the presence of asymmetric information (the university/inventor know the value of invention but established firm does not know the value) but adding the possibility that licensing is not always profitable for the firm. This extends Samuelson&Bazerman model, in which trade is always profitable if it were symmetric information.

The rest of the paper is organized as follows: Section II provides a short description of the licensing process involving the use of secrecies, Section III presents the theoretical model and its implications, Section IV includes a welfare analysis and conclusions are included in Section V.

## II. A Short Description of the Licensing Process

The licensing mechanism consists of three main phases:

*Phase 1 - Invention's Disclosure.* The invention is disclosed to the university technology transfer office in order to protect its property rights and market the invention.

*Phase 2* Firms may use of confidential agreements, *secrecies*, which give firms the opportunity to learn about the quality of invention and determine whether they are interested in licensing the invention.

*Phase 3 – Licensing.* If firms decide to license the invention then they start a bargaining process with the university regarding the license fee.

I model licensing as a two-stage process: in the first stage the firm decides whether to enter a secrecy agreement in order to learn the profitability of the invention. In the second stage the firm makes an offer to the university in order to license the invention. If the offer is accepted by the university, the firm commits to a license agreement by paying a license fee. If the offer is not accepted, the university has the option to negotiate a license agreement with the inventor.

It is important to note the presence of the adverse selection in the licensing process. That is, a given offer will only be accepted by the university for the “low-value“ inventions<sup>1</sup>.

## III. A model of bilateral bargaining

My bargaining model extends the analysis of Samuelson&Bazerman (1985) by adding the option of entering a secrecy agreement to reduce the uncertainty about the profitability of the license.

The model has two stages: 1) the firm (the *buyer*) chooses whether to enter a secrecy and 2) the firm makes a first-and-final offer which is accepted or declined by university (*seller*). If the invention is declined by the firm then the university has the option licensing the invention to the *inventor*. The main elements of the model can be described as follows: a risk-neutral firm is deciding whether to license an invention from the university. The invention's value  $v$  is drawn uniformly from the interval  $[\underline{v}, \bar{v}]$  and has

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<sup>1</sup> In practice, the adverse selection is mitigated by the financing constraints faced by the inventor. Without borrowing constraints the inventors could secure the necessary financing for developing the high quality inventions. But due to lack of collateral and uncertainty about the quality of inventions inventors may not be able to raise the necessary financial resources necessary for the development of the inventions. The presence of imperfect in the capital markets reduces the adverse selection problem for the established firms.

a cumulative probability distribution  $F(v)$ . The firm, the university and the inventor know the function  $F(v)$ , but only the university and the inventor know the specific value of  $v$ .

Suppose that the firm incurs a constant and exogenous cost  $c_A$  associated with developing the invention, which is uniformly distributed over the interval  $[\underline{v}, \bar{v}]$ . Notice that licensing the invention is not always profitable for the firm because there is a positive probability that the value of the invention is lower than the cost  $c_A$ .

Furthermore, assume that the inventor's cost of production is  $c_0$  and is also uniformly distributed on  $[\underline{v}, \bar{v}]$ . The costs of production for firm and inventor are assumed to be independent and identically distributed. The costs  $c_0, c_A$  and the function  $F(v)$  are known to all players of the model at the beginning of the bargaining process.

In the first stage of the bargaining process, the firm has the option to enter a secrecy agreement at a cost  $c_s$  to ensure the profitability of the invention.

In the second stage, a bilateral bargaining process takes place between firm and the university. The rules of the bargaining are: the firm makes a first and final offer to the university and this offer is accepted or declined. If the offer is accepted, the firm pays a price  $p$  for the use of the invention. If the offer is declined, the university has the option of negotiating a license with the inventor, who licenses the invention if  $v \geq c_0$ <sup>2</sup>.

Given the rules specified above, the payoffs of the players in the second stage are determined as follows: if the firm's offer is accepted then the firm licenses the invention and pays a price  $p$  to the university. The payoff of the firm is then:  $\max\{0, v - c_A\} - p$  and the payoff of the university is  $p$ . Notice that the firm's payoff incorporates the fact that, having paid the price  $p$  to the university, it learns the value

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<sup>2</sup> Multiple licenses are possible for the same invention. For simplicity I assume that firms cannot sublicense the invention and that the profitability of the license to firm A does not depend on the number of other potential licensees.

of the invention  $v$  and pursues the invention only if  $v \geq c_A$ . If  $v < c_A$ , the firm does not pursue the invention and incurs a loss  $-p$ .

If the firm's offer is rejected and  $v \geq c_0$ , then the inventor licenses own invention by paying a price  $(v - c_0)$ . As a result, the inventor's payoff is 0 and the payoff for the university is  $(v - c_0)$ . If the offer is rejected and  $v < c_0$ , then the invention remains unlicensed and both the university and the inventor get a payoff of 0. Overall, if the offer is rejected, the payoff to the university is:  $\max\{0, v - c_0\}$  and the inventor's payoff is 0.

First, I describe the bargaining outcome when the firm does not have the option of entering secrecy. Later in the paper I describe the bargaining outcome when the firm has the option of using the secrecy device.

Assume for the rest of the paper that  $c_A \leq c_0$ , i.e. the firm is more efficient than the inventor in developing the invention<sup>3</sup>.

### **Bargaining Outcome without the secrecy device**

Denote by  $p_b$  the firm's offer for licensing the invention. An offer  $p_b \geq 0$  is accepted by the university if and only if:  $p_b \geq v - c_0$ , or alternatively,  $v \leq p_b + c_0$ . Conditional on an offer  $p_b$  being accepted, the firm updates its beliefs about the value and infers that it is in the interval  $[v, c_0 + p_b]$ .

The conditional value of the invention is uniformly distributed over  $[v, c_0 + p_b]$  with probability

$$\text{distribution function: } g(v) = \frac{1}{c_0 + p_b - v}.$$

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<sup>3</sup> If  $c_0 < c_A$  the analysis is as follows: if the licensing process does not include the use of secrecy then any positive offer by the firm and accepted by the university will result in negative profits for the firm since the offer is accepted if  $p_b \geq v - c_0 > v - c_A$ . If the firm offers 0, then this offer is accepted only if  $v < c_0$ . And since  $c_0 < c_A$ , then  $v < c_A$  which again leads to negative profits. The firm will not develop the invention in this case. As result, when  $c_0 < c_A$ , the firm is indifferent between bidding 0 or making no offer and it makes 0 profit. The invention is licensed by the inventor only if  $v > c_0$ , in which case the university's expected profit is  $\frac{(v - c_0)^2}{2(v - v)}$ , otherwise the invention remains unlicensed. If the firm has the option of using the secrecy

then, by a similar reasoning, the optimal strategy for the firm is *not to enter* a secrecy and being indifferent between offering 0 or not making an offer for the invention.

The probability that the invention is not profitable for the firm is:  $\frac{c_A - \underline{v}}{c_0 + p_b - \underline{v}}$  and the probability

that the invention is profitable for the firm is:  $\frac{c_0 + p_b - c_A}{c_0 + p_b - \underline{v}}$ .

The firm's net expected profit conditional on the offer  $p_b > 0$  being accepted is:

$$E_0(\Pi) = \int_{\underline{v}}^{c_0 + p_b} \{\max(v - c_A, 0) - p_b\} g(v) dv = \int_{\underline{v}}^{c_A} (0 - p_b) g(v) dv + \int_{c_A}^{c_0 + p_b} (v - c_A - p_b) g(v) dv \quad (\text{I})$$

From (I), the formula for the expected profit can be written as follows:

$$E_0(\Pi) = \frac{c_A - \underline{v}}{c_0 + p_b - \underline{v}} (0 - p_b) + \frac{1}{c_0 + p_b - \underline{v}} \left[ \frac{(c_0 + p_b)^2}{2} - (c_A + p_b)(c_0 + p_b) - \frac{c_A^2}{2} + (c_A + p_b)c_A \right]$$

This formula takes into account that the firm, having paid  $p_b$  for the invention, learns the true value  $v$  and develops the invention if and only if  $v \geq c_A$ . Otherwise, the payoff to the firm is  $-p_b$ .

The firm is maximizing the expected profit and the first-order condition associated with this problem is:

$$-(c_A - \underline{v}) + c_0 + p_b - 2p_b - c_0 - c_A + c_A = 0,$$

from which we obtain the firm's optimal offer:  $p_b^* = \underline{v} - c_A$ .

Since  $c_A \geq \underline{v}$  and  $p_b \geq 0$ , then firm's optimal offer becomes  $p_b^* = 0$ . In equilibrium, this offer must be accepted if  $v < c_0$  (the invention is worthless for the inventor) the university makes 0 profit.

The net expected profit for the firm when it offers  $p_b^* = 0$  and the offer is accepted is:

$$E_0(\Pi) = \frac{(c_0 - c_A)^2}{2(c_0 - \underline{v})}. \quad (\text{II})$$

The firm's net expected profit is proportional with the difference between the cost of production of firm and inventor's cost of production. The more efficient the firm is relative to the inventor, the higher is its expected profit<sup>4</sup>.

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<sup>4</sup> Notice that the value of the expected profit in this case represents the value of the integral for the profit function between  $c_A$  and  $c_0$ .

The derivation for (II) takes into account that neither party pursues the invention if  $v$  is lower than his cost of production.

This analysis shows the impact of the asymmetric information on the possibility of mutual gain. Even though there are cases in which it is profitable for the firm to license the invention, a positive offer would result in a lower net expected profit. This is due to adverse selection<sup>5</sup>.

### Bargaining outcome with secrecy device

I assume that, before licensing, the firm has the option of entering a secrecy by paying a cost  $c_s$ . Having entered a secrecy, the firm learns the value of the invention  $v$  and makes an offer if  $v \geq c_A$ .

If  $v < c_A$ , then the firm does not make an offer and incurs the cost  $c_s$  (i.e. the cost of secrecy is sunk). The net expected payoff for the firm is then:  $-c_s$ .

If  $v \geq c_A$  the firm's optimal offer is derived as follows: if  $v < c_0$ , the offer is  $p_b^s = 0$ . If  $v \geq c_0$  the offer is:  $p_b^s = v - c_0$ . As a result, if  $v \geq c_A$ , the firm's optimal offer can be written as:  $p_b^s = \max\{0, v - c_0\}$ . Overall, the firm's net expected payoff is:  $\max\{0, v - c_0\} - c_s$ .

The firm's ex-ante expected profit when entering a secrecy is:

$$\begin{aligned} E_1(\Pi) &= \int_{\underline{v}}^{\bar{v}} \{\max(v - c_A, 0) - p_b^s\} f(v) dv - c_s = \int_{\underline{v}}^{c_A} 0 \cdot f(v) dv + \int_{c_A}^{c_0} (v - c_A - 0) f(v) dv + \int_{c_0}^{\bar{v}} (c_0 - c_A) f(v) dv - c_s \\ &= \frac{1}{v - \underline{v}} \left[ \frac{c_0^2 - c_A^2}{2} - c_A(c_0 - c_A) \right] + \frac{c_0 - c_A}{v - \underline{v}} (\bar{v} - c_0) - c_s. \end{aligned}$$

The calculations show that:

$$E_1(\Pi) = \frac{c_0 - c_A}{(v - \underline{v})} \left[ \bar{v} + \frac{c_0 + c_A}{2} \right] - c_s \quad (III)$$

Therefore, the firm enters a secrecy if and only if  $E_1(\Pi) \geq 0$ , which implies that:

<sup>5</sup> A given offer is accepted by the university only for lower value inventions.

<sup>6</sup> The calculation takes into account that the firm, having paid the cost of a secrecy  $c_s$ , learns the value of the invention  $v$  and makes an offer only if  $v \geq c_A$ . Otherwise, the invention remains undeveloped and the payoff to the licensee is  $-c_s$ .

$$(c_0 - c_A)\left[\bar{v} + \frac{c_0 + c_A}{2}\right] \geq c_s(\bar{v} - \underline{v}). \quad (\text{IV})$$

### The effect of $c_s$ on buyer's decision to enter a secrecy

The cost of entering a secrecy has a direct effect on the firm's decision to enter a secrecy, as shown by (IV).

Notice first that, if the cost of the secrecy were 0, (IV) always holds so the firm benefits by entering a secrecy. If the cost of a secrecy is too high (relative to the difference in the costs between the firm and inventor) then the firm may be deterred from entering<sup>7</sup>.

To analyze in more detail the effect of  $c_s$  on the secrecy choice, we can rewrite (IV) as:

$$c_s \leq \frac{1}{\bar{v} - \underline{v}} (c_0 - c_A) \left( \bar{v} + \frac{c_0 + c_A}{2} \right) \quad (\text{IV.1}).$$

In analyzing (IV.1) it is useful to consider a special case first. When the costs of the firm and university are almost equal (we can make equal at the limit), then for any positive  $c_s$  the secrecy condition (1) does not hold. The firm will not enter a secrecy because the expected profit from entering a secrecy, which is proportional to the difference in costs, is very small and offset by the cost of secrecy.

Denote by  $\bar{c}_s$  the RHS of (IV.1), whose value is determined by  $c_A, c_0, \underline{v}$  and  $\bar{v}$ . Then, (IV.1) implies that for values of  $c_s$  greater than  $\bar{c}_s$  it would be unprofitable for the firm to enter a secrecy<sup>8</sup>.

As a results, if  $c_s$  is zero then all firms would enter secrecies and if  $c_s$  is greater than  $\bar{c}_s$  then the licensing process with secrecies would be equivalent to that without secrecies<sup>9</sup>.

<sup>7</sup> The gains in the expected profit which is based on the difference between the firm's cost and inventor's cost could be offset by the high cost of secrecy.

<sup>8</sup> In fact, the maximum value of  $\bar{c}_s$  is  $\frac{3\bar{v} + \underline{v}}{2}$ , and it is reached when  $c_A = \underline{v}$  and  $c_0 = \bar{v}$ . If  $c_s > \bar{c}_s$  then the firm's offer is 0 and trade takes place.

<sup>9</sup> Given  $c_0$  and  $c_A$ , (IV.1) determines an interval for  $c_s$  over which it is profitable for firm to enter a secrecy. Furthermore, within this interval, the expected profit from entering a secrecy is greater than the expected profit from not entering a secrecy if  $c_s \in [0, c_s^*]$ , where  $c_s^* < \bar{c}_s$ . The intuition is that if  $c_s$  is less than  $c_s^*$  then entering a secrecy enhances the expected profit by reducing the asymmetry of information.

The cost of secrecy induces a *selection effect*, i.e. for a given  $c_s$  only the more efficient firms (relative to the inventor) will find it profitable to enter secrets.

To further analyze the firm's decision to enter a secrecy, I rewrite condition (IV) as:

$$(\bar{v} - \underline{v})c_s - c_0\left(\bar{v} + \frac{c_0}{2}\right) + c_A\bar{v} + \frac{c_A^2}{2} \leq 0 \quad (\text{V})$$

The LHS of (2) is a quadratic function in  $c_A$  and it has 2 real solutions if the discriminant  $\Delta = \bar{v}^2 - 2[(\bar{v} - \underline{v})c_s - c_0(\bar{v} + \frac{c_0}{2})]$  is positive, condition which is satisfied for large values of  $\bar{v}$ .

The roots of the quadratic function are:  $c_A^{1,2} = -\bar{v} \pm \sqrt{\Delta}$  and so condition (V) is satisfied if  $c_A \in [-\bar{v} - \sqrt{\Delta}, \sqrt{\Delta} - \bar{v}]$ .

However,  $c_A \geq \underline{v}$  (by assumption) and thus (V) implies that  $c_A \in [\underline{v}, \sqrt{\Delta} - \bar{v}]$ . (VI)

The firm enters a secrecy if and only if conditions (V) and (VI) are satisfied. As a result, if the firm's cost of production is small enough then entering a secrecy is profitable.

Conversely, the firm does not enter a secrecy if:  $c_A \in (\sqrt{\Delta} - \bar{v}, \bar{v}]$ . (VII)

In the case when the firm does not have the opportunity to enter secrets, due to adverse selection, the optimal bid for invention is 0 and the firm's net expected profit when the offer is accepted is:

$$E_0(\Pi) = \frac{(c_0 - c_A)^2}{2(c_0 - \underline{v})}$$

When the firm has the opportunity to enter the secrecy but did not use it, the condition (VII) must be true. As required by a PBNE, the actions of the firm must consistent with its beliefs about the value of invention. In addition, given the firm's beliefs about the value, the firm's actions are optimal.

The firm's expected profit when no secrecy is taken needs to be consistent with (VII):

$$E_1(\Pi | c_A > \sqrt{\Delta} - \bar{v}) = \frac{(c_0 - c_A)^2}{2(c_0 - \underline{v})} \Big|_{c_A > \sqrt{\Delta} - \bar{v}}, \text{ and the optimal offer is: } p_b^* = 0.$$



As a conclusion, in a PBNE, the firm of type  $c_A \in [\sqrt{\Delta} - \bar{v}, \bar{v}]$  does not enter a secrecy and the optimal bid is  $p_b^* = 0$ . If the firm is of type  $c_A \in [\underline{v}, \sqrt{\Delta} - \bar{v}]$  then it enters a secrecy and the optimal bid is as follows:  $p_b^* = 0$  if  $v < c_0$  and  $p_b^* = v - c_0$  if  $v \geq c_0$ .

#### IV. Welfare Implications of the secrecy device

I analyze the welfare implications for the licensing process when the firm can use the secrecy device. Collectively, a standard measure of efficiency is given by:

$$W = E^b(\Pi) + E^s(\Pi), \quad (\text{VIII})$$

where  $E^{b,s}(\Pi)$  represent the ex-ante profit of the buyer and seller respectively.

The main results of the paper are:

(a) If the firm does not have the opportunity to enter a secrecy and  $c_A < c_0$ , then the firm's offer

is:  $p_b^* = 0$ , the firm's expected profit is  $E_0(\Pi) = \frac{(c_0 - c_A)^2}{2(c_0 - \underline{v})}$  and trade takes place only if  $v \leq c_0$ <sup>10</sup>.

The intuition is the following: due to adverse selection and in order to avoid potential losses from a positive bid, the buyer bids 0.

The university's profit is as follows:  $\Pi^s = 0$  if  $v \leq c_0$  and  $\Pi^s = v - c_0$  if  $v > c_0$ . Thus, the ex-

ante expected profit for the university is:  $E^s(\Pi) = \frac{(\bar{v} - c_0)^2}{2(\bar{v} - \underline{v})}$ .

As a result, in case (a) the collective welfare is:  $W_0 = E^b(\Pi) + E^s(\Pi) = \frac{(c_0 - c_A)^2}{2(c_0 - \underline{v})} + \frac{(\bar{v} - c_0)^2}{2(\bar{v} - \underline{v})}$ . (IX)

(b) When the firm has the opportunity of entering a secrecy, at a cost  $c_s$ , then the PBNE is as follows:

(b.1) if the firm type is  $c_A \in [\sqrt{\Delta} - \bar{v}, \bar{v}]$  then it does not enter a secrecy, the optimal bid is  $p_b^* = 0$  and trade takes place if  $v \leq c_0$ .

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<sup>10</sup> Trade here refers to a licensing agreement between the buyer and university and not a licensing agreement between university and inventor.

The ex-ante profits of the firm and university are respectively:  $E_1^b(\Pi) = \frac{(c_0 - c_A)^2}{2(c_0 - \underline{v})}$ ,  $E^s(\Pi) = \frac{(\bar{v} - c_0)^2}{2(\bar{v} - \underline{v})}$ .

The collective welfare equals  $W_0$ , as in case (a).

(b.2) if the firm type is  $c_A \in [\underline{v}, \sqrt{\Delta} - \bar{v}]$  then it enters a secrecy and the optimal bid is as follows: if  $v < c_0$  then  $p_b^* = 0$ , otherwise  $p_b^* = v - c_0$ . Trade takes place in both cases and the ex-ante profits for

the firm and university are respectively:  $E_1^b(\Pi) = \frac{(c_0 - c_A)(2\bar{v} + c_0 + c_A)}{2(\bar{v} - \underline{v})}$  and  $E^s(\Pi) = \frac{(\bar{v} - c_0)^2}{2(\bar{v} - \underline{v})}$ .

The collective welfare in this case is:

$$W_1 = E^b(\Pi) + E^s(\Pi) = \frac{(c_0 - c_A)(2\bar{v} + c_0 + c_A)}{2(\bar{v} - \underline{v})} + \frac{(\bar{v} - c_0)^2}{2(\bar{v} - \underline{v})}. \quad (\text{X})$$

The secrecy device eliminates the asymmetry of information and the adverse selection. Thus, the two parties involved in the bargaining can trade efficiently by allowing the more efficient player to license the invention. If the firm is a low-cost type, then the parties enjoy gains in welfare since  $W_1 > W_0$ . The gain in welfare gain is:

$$\Delta W = \frac{(c_0 - c_A)(\bar{v} - c_0)(c_0 + c_A - 2\underline{v})}{2(\bar{v} - \underline{v})(c_0 - \underline{v})}. \quad (\text{XI})$$

The increase in welfare is proportional with the difference in the two costs of production. The bigger is the difference in the costs, the higher are the welfare gains due to the use of secrecy device.

As a conclusion, the collective welfare increase weakly when the licensing process incorporates a secrecy device for firms.

## V. Conclusions

The paper uses a bargaining model with adverse selection to analyze the efficiency of the licensing process when firms have the option of using the secrecy device. Firms face an adverse selection issue in the absence of the secrecy device and the optimal bid for the inventions is zero. This bid is accepted by the university only for lower quality inventions. Inefficiency occurs because there some of the higher quality inventions are not licensed by the most efficient player. If the licensing process has the option of the

secrecy device, then firms use these secrets to ensure the profitability of invention and eliminate the asymmetry of information regarding the value of invention. In this case, the low-cost firm enters secrets and bid successfully on the invention. This leads to a net gain in the collective welfare of the players.

Another main result is that the gain in welfare is proportional to the difference in the costs of production between the firm and the inventor.

As a main conclusion, the theoretical model presented in this paper predicts that the secrecy device enhances the efficiency of the licensing mechanism by eliminating the adverse selection and asymmetry of information. The results have direct public policy implications, suggesting ways of designing and implementing a more efficient licensing process.

This model can be extended to analyze the welfare implications if multiple licensees are allowed for the same invention<sup>11</sup>. Another direction of research is analyzing the welfare implications of the licensing process with the secrecy device in the presence of liquidity constraints faced by the inventor.

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<sup>11</sup> One assumption could be that the profitability of the invention decreases with the number of licensees.

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## **Chapter 3**

### Stage of development and licensing university inventions

### Abstract

In this chapter I analyze the correlation between the licensing activity by start-ups and established firms and the inventions' stages of development. Using a new variable to characterize the inventions, stage of development, I also study the correlation between this variable and two other outcomes: patenting activity and royalty generation.

The decision of firms to license at various stages of development could be affected by comparative advantage principle or by asymmetry of information.

The main results show that the relative likelihood of licensing by start-ups to licensing by established firms is lower for more advanced stage inventions relative to earlier stage inventions. The results regarding the change in relative likelihood ratio across stages of development also hold when I use other outcome variables, like patenting and royalty creation

## I. Introduction

This paper examines the correlation between the characteristics of university inventions and firms' licensing activity. Start-up and established firms are important vehicles of diffusion of new technology to the market place. The goal of the paper is to provide empirical evidence describing the differences in licensing activity by start-ups and established firms with regard to the inventions' stages of development. The main question addressed here is: *Are start-ups (inventor founded firms) more likely to license inventions at earlier stages of development than established firms do?* Using a new variable that describes the stage of development of inventions the paper compares the relative likelihood of licensing by start-ups to licensing by established firms for early stage inventions relative to late stage inventions. My results show that relative likelihood of licensing by start-ups to licensing by established firms is lower for more advanced stage inventions relative to earlier stage inventions. The results regarding the change in relative likelihood ratio across stages of development also hold when I use other outcome variables, like patenting and royalty creation.

Numerous studies on research activity at universities, namely using patent data, analyze how the informational and technical characteristics of inventions affect the licensing process. However, this is the first study to describe the correlation between the stages of development and licensing activity by start-up and established firms.

A better understanding of the nature of firms' involvement in licensing is important from a public policy perspective. The research activity at universities is mainly funded by government sources and so it is important to understand whether university technology is transferred efficiently to achieve the highest possible returns on public investment. In an empirical study of licensing activity at MIT, Shane (2002) argues conceptually that established firms have several advantages over the start-ups: higher efficiency based on economies of scale, better marketing expertise and an established customer base and more financial resources and complementary assets needed in developing the inventions. Start-ups (inventor-founded firms), in turn, benefit from the inventor's participation which eliminates the tacit knowledge issue. In addition, inventors provide a better working knowledge with these inventions. Overall, the existing studies reflect how licensing by firms is associated with both established firms' comparative

advantage in commercializing the invention and inventors' comparative advantage in working with the invention.

Describing the correlation between the invention's stage of development and licensing activity is a first step in analyzing other complex issues (e.g. efficiency of the licensing process). For example, if different stages of development are characterized by a different amount of tacit knowledge and transparency, then understanding the nature of this correlation would provide us with an extra tool which can be used in studying the extent to which different types of firms license inventions based on comparative advantage or asymmetric information.

This study uses a unique data set from the Technology Transfer Office at UC San Diego regarding the disclosure of inventions and licensing activity by start-up and established firms. The campus has intense research activity, being a leader among the nation's research institutions. UCSD has consistently ranked fourth or fifth overall in the nation based on contract and grant funding data from NSF.

The rest of the paper is organized as follows: Section II includes the literature review and theoretical implications, Section III describes the data, Section IV presents the main results and conclusions are included in Section V.

## **II. Literature review and theoretical implications**

Commercialization of university inventions depends on the successful transfer of knowledge and skills involved in working with the technology from the inventor to the licensee. It is based on marketing skills, prototype development and manufacturing capabilities. Conceptually, Shane (2002) suggests that since these market skills are acquired through a process of learning-by-doing then one would expect that established firms are more likely to possess them. Start-ups, on the other hand, benefit from the inventor's superior understanding of working with own inventions<sup>1</sup>. In a recent survey on inventions licensed from universities, Jensen and Thursby (2001) show that a great proportion of the inventions are in early stages but they do not describe what types of firms (start-ups vs. established) license them, which I do in this paper. The main objective of my paper is to highlight empirically the correlation between the licensing

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<sup>1</sup> Teece (1980) suggests conceptually that the possibility of firms specializing in their comparative advantage would maximize the gains from trade.



activity by start-ups and established firms and the invention's stages of development<sup>2</sup>. Licensing of early stage inventions would provide start-ups with a comparative advantage over established firms because, as suggested conceptually by Shane (2001), product innovation and technology development are more important than economies of scale at this stage of invention's life.

A first best outcome in the market for university inventions with perfect information suggests that established firms license all inventions due to their comparative advantage in manufacturing and commercialization.

This outcome may not be always attainable due to the inability to effectively contract the tacit knowledge. As a consequence, it is possible that some inventions may not be taken by the firms with comparative advantage in commercializing them, i.e. established firms<sup>3</sup>. Shane (2002) suggests that, in the presence of market imperfections, licensing to a start-up firm is a "second-best" solution because start-ups do not have the comparative advantage in commercializing the inventions. Shane (2000, 2001) examines empirically the correlation between the technological properties of the inventions (e.g. effectiveness of patents) and the likelihood of license by start-up or established firms. He finds that young technologies are more likely to be licensed by new firms because the markets associated with these technologies are too small for the established firms and because the new firms can compete on the basis of differentiation rather than costs.

Lowe (2002) shows empirically how the decision to start a firm and license own invention is associated with the fact that technological uncertainty and tacit knowledge raise the cost of licensing for the outside firms.

The main contribution of my paper is that it uses a different and new technological characterization for the invention – i.e. stage of development – to study the relative likelihood of licensing by start-ups to licensing by established firms across various stages of development. The advantage of the stage of development variable is that it can be used for all disclosed inventions, not just for the patented

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<sup>2</sup> Using a theoretical approach, Thursby&Jensen (1998) argue that since most of university inventions are embryonic then a great part of these inventions would remain undeveloped without the further input of the inventor. As a result, licensing contracts have to include an incentive scheme (royalties, equity) to reduce the moral hazard problem.

<sup>3</sup>Anton and Yao (1994) suggest theoretically that inventors have an incentive to limit the disclosure of information because once this information is revealed the established firms have no incentive to pay for it.

ones. Another contribution of the paper is that, in contrast to Lowe (2003), I examine the correlation between the stage of development and two other important events: patenting and royalty creation.

The arguments presented by the comparative advantage theory of licensing lead to the following hypothesis. If economies of scale and informational asymmetries<sup>4</sup> are important criteria in licensing by firms, then the relative likelihood of licensing by start-ups to licensing by established firms should be lower for the inventions ready for commercialization than for conceptual ones. The correlation between the licensing activity by established firms and the ready stage inventions is likely to be higher than the correlation with earlier stage inventions because they have a comparative advantage in manufacturing and commercialization activities. The correlation between the licensing by start-ups and conceptual inventions is likely to be higher than the correlation with ready inventions due to their superior knowledge in working with the conceptual inventions.

### **III. Data**

I analyze a data set of 700 inventions disclosed to the Technology Transfer Office at University of California, San Diego between 1986-2003<sup>5</sup>. The unit of analysis is an invention and is based on a disclosure by a researcher or faculty member at the university. The inventions are grouped into four main fields based on the primary line of research: medicine, chemistry & biochemistry, electrical & engineering and marine studies. For each invention, the stage of development at time of disclosure was identified as one of the following categories: CONCEPT, PRECLINICAL, PROTOTYPE, and READY.

The stages are defined as follows: CONCEPT: invention is only a proof of concept; PRECLINICAL: invention at the level of target discovery/validation, assay development or lead selection<sup>6</sup>; PROTOTYPE: invention is a prototype at the lab scale and READY: invention is ready for practical or commercial use.

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<sup>4</sup> Informational asymmetries refer to the fact that start-ups have a better working knowledge with the technology.

<sup>5</sup>This data set is based on all 1,069 inventions disclosed except I have excluded the copyrightable inventions (244), which have a different standard of intellectual protection and licensing, and inventions for which I was unable to match the corresponding grant amounts (125).

<sup>6</sup>Lead selection is a non-linear process of refining the chemical structure of a confirmed compound to improve its drug characteristics with the goal of producing a preclinical drug candidate

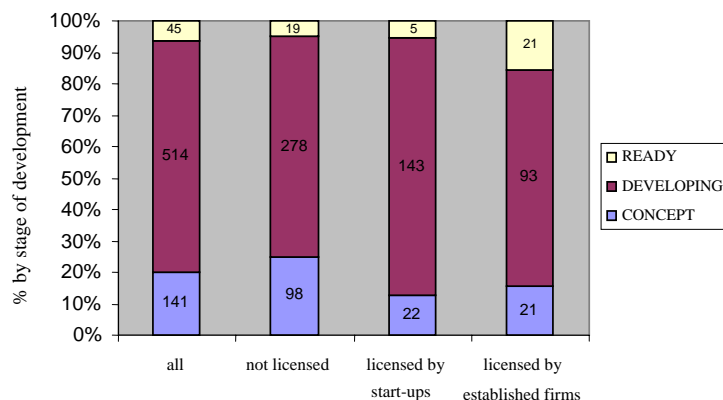
Even though there are four types of stages, a given invention can only be in one of the following three stages: 1) CONCEPT, 2) PROTOTYPE or PRECLINICAL and 3) READY. For example, an invention in chemistry & biochemistry field (e.g. an invention for a new drug) can be in one of the stages: concept, preclinical or ready but not in prototype. An invention in electrical&engineering field can be in one of the stages: concept, prototype or ready but not in preclinical. Thus, I cannot compare directly the PRECLINICAL and PROTOTYPE stages. I can directly compare the following stages: CONCEPT (very early), PRECLINICAL/PROTOTYPE (developing stage) and READY (late stage).

It is important to note that I do not explicitly model the inventor's choice to disclose the invention at various stages of development. I assume that the stage of development is not strategically reported by inventor.

The distribution of all 700 inventions by stages of development is: 141 inventions or 20% are in CONCEPT stage, 514 inventions or 73.5% are in DEVELOPING stage, and 45 inventions or 6.5% are in the READY stage of development.

The primary event of interest in this paper is licensing by firms. Out of 700 inventions disclosed, only 305 inventions (44%) were licensed by either start-ups or established firms. The sub-sample of licensed inventions can be divided as follows based on the type of licensee: 170 inventions were licensed by start-ups and 135 were licensed by established firms. Graph 1 summarizes the distribution of inventions by stage of development for each type of licensee:

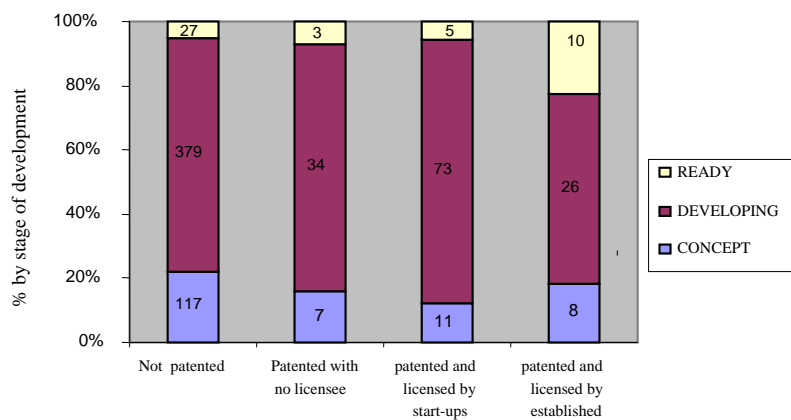
Graph 1, Chapter 3. Distribution of inventions by stage of development and licensing outcome



There are other alternative outcome measures one could look at: patenting and royalties. In principle, UC San Diego could follow a patenting policy independent of licensing as was the case before 1990. Due to increasing patenting costs and reduced operating budget, after 1990 TechTIPS decided to patent an invention only if a licensee agreed to pay for the patenting costs. My data set distinguishes the following categories of inventions: inventions never patented, patented with no licensee, patented and licensed by start-ups and patented and licensed by established firms.

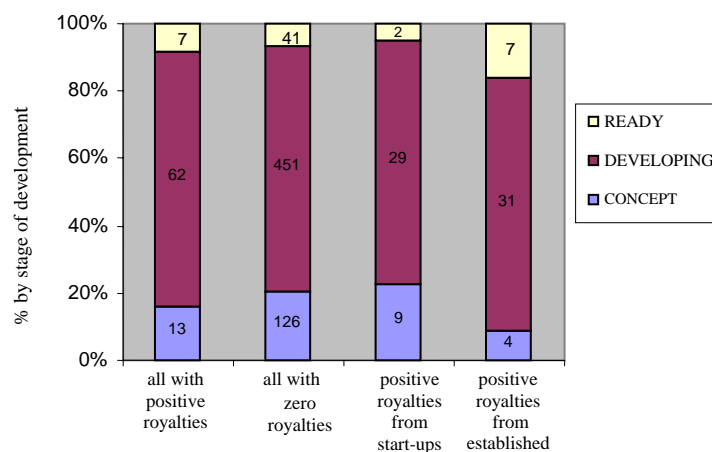
Out of the 305 licensed inventions: 133 inventions were patented, 82 inventions generated royalties and only 36 of licensed inventions that generated royalties were patented. Graph 2 shows the distribution of inventions by stage of development and the patenting activity:

Graph 2, Chapter 3. Distribution of inventions by stage of development and patenting outcome



The amount of royalties received by the university as a result of licensing activity increased steadily over the last decade. Royalties, which are based on the sales generated by commercializing the invention, occur only as a result of a licensing decision. Graph 3 shows the distribution of inventions with positive royalties by stages of development:

Graph 3, Chapter 3. Distribution of inventions by stage of development and positive royalties



The data presented in the descriptive statistics from Tables 1-3 is used in Section IV to compare the licensing (and the two other outcome measures: patenting and royalty generation) behavior of start-ups and established firms across various stages of development. The empirical strategy in the next section employs the stages of development as main explanatory variables and a set of control variables.

The control variables included in the analysis are: Tenure, Experience, field dummies and invention's age in years at the time of license, calculated from the time of disclosure<sup>7</sup>. The first two variables characterize the quality of the inventor. For example, past licensing experience provides reputation of successful inventions which in turn influences the propensity of licensing because it increases the expectation of the success (quality) of the invention to be licensed.

The descriptive statistics of the control variables are included in Table 1. The mean for both the experience and tenure variables is less than one because they are coded as binary variables.

<sup>7</sup> A complete description of these variables is provided in Chapter 1 of my dissertation.

In addition to these variables I collected information and created a new and unique quality variable which was not used in any previous studies: Grant – a variable defined as the log of total grant amounts received by the inventor during 1986-2003 divided by number of year since the PhD degree was obtained<sup>8</sup>.

#### IV. Specification and Results

There are three possibilities for the licensing event: licensing by start-ups, licensing by established and not licensed. I expect that for inventions at more advanced stages the odds ratio for licensing by a start-up relative to licensing by established firm is lower than for inventions at earlier stages. I focus on the licensing process and I return to analysis of other outcomes, such as patenting and royalties generation later in the paper.

The probability that any firm of type  $i$  licenses an invention at stage  $s$  is:

$$\text{Prob (type } i \text{ licenses at stage } s) = \alpha_i^s = \frac{\exp(\xi_i^s)}{1 + \sum_j \exp(\xi_j^s)}, \text{ where}$$

$$\xi_i^s = \beta_i^{\text{ready}} \cdot \text{READY} + \beta_i^{\text{developing}} \cdot \text{DEVELOPING} + \beta_i \cdot X \text{ and } s \in \{\text{DEVELOPING, READY}\}$$

such that if  $s = \text{DEVELOPING}$  then  $\text{DEVELOPING} = 1$  and  $\text{READY} = 0$ ,

if  $s = \text{READY}$  then  $\text{READY} = 1$  and  $\text{DEVELOPING} = 0$ , and

$X = \{\text{grant, experience, tenure, age, field controls}\}$  is a vector of covariates characterizing the quality of invention, inventor and controls for technological fields.

Notice that the specification of the probability of license presented above assumes that the CONCEPT stage is the comparison group.

To find the unconditional probability of license for type  $i$  firm of an invention at stage  $s$ , i.e.  $\overline{\alpha_i^s}$ , one just sets all covariates at their means.

The odds ratio of greatest interest is defined as the ratio of the probability of start-ups licensing an invention at stage  $s$  to the probability of established firm licensing an invention at stage  $s$ :

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<sup>8</sup> The total grants amount is divided by the number of years for which I actually observe the grant data.

Odds ratio = prob (type su licenses at stage  $s$ ) / prob (type ef licenses at stage  $s$ ) =  $\frac{\alpha_{su}^s}{\alpha_{ef}^s}$ , where ‘su’ and

‘ef’ subscripts stand for start-up and established firms respectively.

The tests I perform compare  $\frac{\alpha_{su}^r}{\alpha_{ef}^r}$  vs.  $\frac{\alpha_{su}^s}{\alpha_{ef}^s}$ , where  $r$  and  $s$  are stages of development. There are

several possibilities of comparison of odds ratio: a) concept vs. ready; b) developing vs. ready; c) concept vs. developing. Alternatively, another way of aggregating the stages of development is to combine inventions in the concept and developing stages into a new category – ‘earlier’ stage inventions and inventions in the developing and ready stages into a new category – ‘later’ stage inventions.

I perform a multinomial logit estimation with three main categories of inventions: never licensed, licensed by start-ups and licensed by established firms.

Examining a single odds ratio for a given stage of development  $s$  would not be as meaningful, however. The propensity of licensing depends on the number of start-ups and established firms in the market. In the absence of information regarding the number of firms in the market, the simple difference is hard to interpret. As a result, the main focus of the analysis is based on the relative difference in likelihood of license between the two types of firms with respect to the stages of development.

The full specification estimation is presented in column (1) of Table 2, Panel A. Specifications in columns (2) and (3) are included to check the sensitivity of the main results with respect to the control variables.

The coefficients in Column (1), Table 2 Panel A suggest that the correlation between the licensing by start-ups and the ready inventions is smaller (relative to concept ones) and there is no difference in the correlations between start-up’s licensing of the concept and developing inventions. In contrast, the correlation between the licensing activity by established firms and ready inventions is higher, relative to concept ones. They are also equally likely to license concept and developing stage inventions. The variables controlling for the quality of invention and inventor are positively correlated with the likelihood of license by the two types of firms. In addition, the age of inventions is positively associated (though not significantly for established firms) with the likelihood of license for both types of firms.

Perhaps, the most logical comparison is between inventions in the ready stage and the ones in concept stage. I test that the odds ratio of licensing by start-ups relative to licensing by established firms is lower for inventions in the ready stage than for inventions in the concept stage.

I define the test statistic:  $\Delta_{concept-ready}^{LIC} \equiv \frac{\alpha_{su}^{ready}}{\alpha_{ef}^{ready}}$  and test whether it is less than 1. I find that the

value of the chi-square(1) test statistic is 12.68 which is significant at better than the 1% level rejecting that  $\Delta_{concept-ready}^{LIC} = 1$ . The odds ratio for licensing by start-ups relative to licensing by established firms is 79% lower for ready inventions than for concept ones.

Instead of comparing concept and ready stages of development, one could use the ready and developing stages of development for comparison. I test that the odds ratio of licensing by start-ups relative to licensing by established firms is lower for inventions in the ready stage than for inventions in developing stage.

I define the test statistics:  $\Delta_{developing-ready}^{LIC} = \frac{\alpha_{su}^{ready}}{\alpha_{ef}^{ready}} - \frac{\alpha_{su}^{developing}}{\alpha_{ef}^{developing}}$  and test whether is less than zero.

The value of the chi-square (1) test statistics is 4.22 which is significant at better than the 5%, rejects that  $\Delta_{developing-ready}^{LIC} = 0$ . The odds ratio of licensing by start-ups relative to licensing by established firms is 81% lower for ready inventions relative to developing ones.

When I compare concept and developing inventions, I cannot reject that  $\Delta_{concept-developing}^{LIC} = 1$ . The odds ratio of licensing by start-ups relative to licensing by established firms is the same for inventions in the concept and developing stages.

The result that odds ratio of licensing by start-ups relative to licensing by established firms is lower for later stage inventions relative to earlier stage inventions is consistent with the comparative advantage principle. Established firms have a comparative advantage over start-ups in commercializing the inventions (including manufacturing, marketing and identifying customer base) so the correlation between their licensing activity and the late stage inventions is higher, because these inventions are closer to commercialization phase. In contrast, start-ups have a comparative advantage over established firms in working with early stage inventions. Thus, the correlation between the licensing activity by start-ups and



the earlier stage inventions is higher, because for these inventions the working knowledge is more important than economies of scale in further developing them.

Using the aggregated stages of development I can compare the odds ratio of licensing by start-ups relative to licensing by established firms across earlier and ready stages and across concept and later stages. The tests are shown in Table 4 and the results are similar to the multinomial logit results from Table 2: the odds ratio for licensing by start-ups to licensing by established firms is lower by 81 % for ready inventions compared to inventions in earlier stage. The odds ratio for licensing by start-ups relative to licensing by established firms is 14 % lower for inventions in later stage relative to inventions in concept stage.

I performed similar tests using other measures of invention performance, patenting and royalties, and the results are included in Table 2, panels B and C<sup>9</sup>. The conclusions are similar to the licensing results from Table 2, panel A: the odds ratio for patenting (royalty generation) by start-ups relative to patenting (royalty generation) by established firms is lower for more advanced stage of development relative to earlier stages of development<sup>10</sup>.

In a robustness check I use a Cox proportional hazard duration model to examine how the stage of development affects the hazard of first license. The duration models use the data more efficiently by taking into account events that have occurred and events that have not occurred, correcting for the effects of censoring. This analysis is based on the timeliness of the events of licensing and royalty generation and allows us to compare the behavior of start-ups and established firms over time. When estimating duration models one can report the coefficients which imply a higher likelihood of an event if the coefficients are positive and a lower likelihood of an event if negative. Alternatively, one can report the hazard ratios which are relatively easy to interpret: a hazard ratio greater than 1 means that the likelihood of the event of interest (licensing or royalty generation) is higher whereas a hazard ratio less than 1 means that the likelihood of interest is lower.

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<sup>9</sup> Notice from the Panel C that the coefficient for developing stage is higher for start-ups than established firms when there are no controls. Once I use the control variables in column 1, this coefficient becomes higher for established firms than for start-ups. This suggests that the stages of development are correlated with the quality of inventor, and these quality variables are more likely to occur in start-ups.

<sup>10</sup> I performed a similar logit analysis by including a dummy variable for start-up on the RHS and interaction terms between this dummy and the stages of development (the inclusion of such a dummy is a common practice in the papers analyzing licensing of university inventions by start-ups and outside firms). This dummy variable is endogenous but the overall results were similar to the multinomial logit.

In Table 3, column (1) I report the estimated hazard ratios of the duration model for the event of first license for start-ups and established firms. The data for this estimation is organized as follows: once an invention is disclosed it is at risk of being licensed by firms. When a license occurs it is categorized as an event in the sense of an event-history. Spells begin at the time of disclosure and end on the date a license is taken or if the end of the sample period was reached (censored observation). For each invention there is an entry for each time at risk and once the invention is licensed or censored then it is removed from the at-risk pool. The covariates take the same values for each time at risk.

The results in Table 3, column (1) show that the correlation between the licensing activity by start-ups and the ready stage inventions is smaller, relative to concept ones. In contrast, the correlation between the licensing activity of the established firms and the ready inventions is higher, as compared to concept ones. A log-rank test of equality of the two duration models is rejected (the value of the chi-square (1) test statistic is 31.12, which is significant at better than 1% level of significance).

The duration analysis was also applied for the event of first royalties and the results are reported in Table 3, column (2). Spells begin at the time of disclosure and end on the date the first royalties are generated or the end of the sample period was reached. The results show that the correlation between the process of royalty generation for start-ups and the developing (or ready) stage inventions is smaller, relative to concept ones. The correlation between the process of royalty generation for established firms and the developing (or ready) stage inventions is higher, relative to concept inventions<sup>11</sup>.

## **V. Conclusions**

In this paper I analyze the correlation between the odds ratio of licensing by start-ups relative to licensing by established firms and the stage of development. The main finding is that this ratio is lower for more advanced inventions relative to inventions in earlier stages of development. This finding suggests the possibility that start-ups could emerge as a vehicle for further developing embryonic inventions which otherwise may not be licensed by established firms. It also shows that the licensing activity of the established firms is positively correlated with later stage inventions. These inventions are more transparent

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<sup>11</sup> This finding at this point is suggestive rather than conclusive. Lowe&Ziedonis (2004) find empirically that start-ups are slightly more likely start generate royalties than are established firms. I propose that a more detailed analysis regarding the role of inventor in the development-commercialization process is necessary in order to obtain more conclusive results.

in regard to their use and commercial value.

Using two other outcome measures, patenting and royalties, I found similar results: the odds ratio of patenting (royalty generation) by start-ups relative to patenting(royalty generation) by established firm is lower when the invention is in later stages of development relative to earlier stages of development.

These results represent a useful starting point in analyzing more complex issues involving the licensing process<sup>12</sup>. Among these issues are: the effects of comparative advantage and asymmetric information on the licensing decision by start-ups and established firms and the efficiency of the licensing mechanism. These issues represent directions of future research.

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<sup>12</sup>In practice, the inventor's decision to disclose or not and at what stage (for the disclosed inventions) depends on the quality of inventor, rate of time preference, attitudes toward publishing and commercialization and other factors.

Table 1, Chapter 3. Descriptive statistics

Variable	Mean	SD	n
age	6	3.5	700
grant	262,093	445,829	700
experience	0.57	0.48	700
tenure	0.75	0.43	700
Medicine	0.67	0.46	700
Chemistry&Biochemistry	0.15	0.25	700
Electrical&Engineering	0.12	0.28	700
Marine Studies	0.07	0.26	700

Table 2. Panel A, Chapter 3. Multinomial logit results for licensing

	(1)		(2)		(3)			
	Coefficients		Relative Risk Ratio		Coefficients		Coefficients	
	su	ef	su	ef	su	ef	su	ef
Developing	0.331 (0.310)	0.277 (0.283)	1.391 (0.432)	1.320 (0.273)	0.810 (0.250)	0.450 (0.260)	0.590 (0.260)*	0.380 (0.270)
Ready	-0.359 (0.108)*	1.206 (0.406)*	0.697 (0.196)*	3.341 (1.359)*	-0.220 (0.080)*	1.510 (0.390)*	-0.11 (0.220)	1.42 (0.390)*
grant	0.161 (0.032)**	0.092 (0.016)*	1.175 (0.106)**	1.096 (0.211)*	no	no	no	no
experience	1.348 (0.237)*	1.099 (0.346)*	3.833 (0.734)*	2.991 (0.627)*	no	no	no	no
tenure	0.338 (0.083)**	0.511 (0.110)**	1.400 (0.476)**	1.664 (0.189)**	no	no	no	no
age	0.126 (0.031)*	0.027 -0.041	1.133 (0.035)*	1.028 (0.041)*	no	no	no	no
control fields	yes	yes			no	no	yes	yes
Observations	700	700			700	700	700	700
Log likelihood	-400.92	-400.92			-677.3	-677.3	-650.9	-650.9
LR chi-square	263.52*	263.52*			28.88	28.88	81.73	81.73
Pseudo R-sq.	0.1893				0.1324		0.1645	

Note: su – start-ups, ef – established; omitted category is CONCEPT

Table 2. Panel B, Chapter 3. Multinomial logit results for patenting

	(1)		(2)		(3)			
	Coefficients		Relative Risk Ratio		Coefficients		Coefficients	
	su	ef	su	ef	su	ef	su	ef
Developing	0.242 (0.099)*	-0.265 (0.457)	1.274 (0.509)	0.766 (0.351)	0.670 (0.340)	-0.050 (0.130)	0.520 (0.250)	-0.030 (0.100)
Ready	-0.122 (0.034)*	1.182 (0.567)*	0.885 (0.145)*	3.263 (1.851)*	-0.280 (0.410)	1.510 (0.510)*	-0.170 (0.420)	1.530 (0.530)*
grant	0.403 (0.165)*	0.164 (0.040)*	1.497 (0.311)**	1.178 (0.265)**	no	no	no	no
experience	0.385 (0.072)	0.266 (0.056)	1.457 (0.179)*	1.306 (0.442)*	no	no	no	no
tenure	0.371 (0.139)*	0.705 (0.243)*	1.449 (0.267)**	2.024 (1.082)**	no	no	no	no
age	0.289 (0.038)*	0.295 (0.046)*	1.333 (0.500)*	1.344 (0.062)*	no	no	no	no
control fields	yes	yes			no	no	yes	yes
Observations	656	656			656	656	656	656
Log likelihood	-319.201	-319.2			-404.7	-404.66	-396.5	-396.5
LR chi-sq. test	188.38*	188.38*			17.45	17.45	33.78	33.78
Pseudo R-sq.	0.2268				0.1211		0.1409	

Note: su – start-ups, ef – established; omitted category is CONCEPT.

The sample used for patenting analysis is a subset of the whole sample where all inventions patented without a firm were removed. I performed a similar analysis using 4 categories for patenting (including the inventions licensed without a firm) and the results are similar.

Table 2. Panel C, Chapter 3. Multinomial logit results for royalty generation

	(1)				(2)		(3)	
	Coefficients		Relative Risk Ratio		Coefficients		Coefficients	
	su	ef	su	ef	su	ef	su	ef
Developing	0.165 (0.301)	0.295 (0.156)	1.040 (0.433)	1.343 (0.381)	0.830 (0.250)*	0.470 (0.260)**	0.620 (0.260)*	0.390 (0.270)
Ready	-0.395 (0.560)	1.194 (0.407)*	0.673 (0.177)*	3.302 (1.344)*	-0.160 (0.200)	1.500 (0.390)*	-0.030 (0.110)	1.410 (0.390)*
grant	0.117 (0.139)**	0.105 (0.027)*	1.124 (0.155)*	1.110 (0.189)*	no	no	no	no
experience	1.698 (0.126)*	1.108 (0.345)*	5.434 (1.456)*	0.018 (0.003)*	no	no	no	no
tenure	0.232 (0.044)*	0.152 (0.045)*	1.375 (0.211)*	1.163 (0.233)	no	no	no	no
age	0.146 (0.027)*	0.022 (0.012)**	1.156 (0.034)*	1.022 (0.020)	no	no	no	no
control field	yes	yes			no	no	yes	yes
Observations	700	700			700	700	700	700
Log likelihood	-574.682	-574.682			-683.1	-683.08	-658.1	-658.05
LR chi-sq test	246.90*	246.90*			30.09	30.09	80.16	80.16
Pseudo R-sq.	0.1768				0.1216		0.1546	

Table 3, Chapter 3. Duration model for the events of the first license and first royalties

	Licensing		Royalties	
	(1)		(2)	
	Hazard Rates		Hazard Rates	
	su	ef	su	ef
DEVELOPING	1.205 (0.316)	1.010 (0.341)	0.658 (0.276)	1.875 (0.789)**
READY	0.327 (0.175)*	3.024 (1.096)*	0.450 (0.064)*	4.436 (3.255)*
grant	1.135 (0.098)*	1.249 (0.034)*	1.094 (0.098)*	1.465 (0.175)**
experience	2.354 (0.319)*	1.786 (0.530)*	1.624 (0.198)**	1.119 (0.329)**
tenure	1.741 (0.054)*	1.112 (0.197)*	1.063 (0.227)**	2.004 (0.845)*
controls for fields	yes	yes	yes	yes
Observations	700	700	700	700
Log likelihood	-919.87	-508.71	-416.69	-401.38
LR for chi-sq test	174.28*	28.83*	45.62*	19.71*

Note: su – start-ups, ef – established; omitted category is CONCEPT.



Table 4, Chapter 3. Summary of the tests statistics for the multinomial analysis

	Licensing	Patenting	Royalties
$\Delta_{concept-ready}$	chi2(1) = 12.68*	chi2(1) = 11.76**	chi2(1) = 18.34*
$\Delta_{developing-ready}$	chi2(1) = 4.22**	chi2(1) = 17.45*	chi2(1) = 9.07*
$\Delta_{concept-developing}$	chi2(1) = 1.15	chi2(1) = 9.49**	chi2(1) = 13.41**
$\Delta_{earlier-ready}$	chi2(1) = 8.87**	chi2(1) = 6.97*	chi2(1) = 7.35**
$\Delta_{concept-later}$	chi2(1) = 10.23*	chi2(1) = 1.56	chi2(1) = 12.33*

Note: \* significant at 1%; \*\* significant at 5%

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