Signaling and the Ownership of Academic Patents

Nicolas CARAYOL
&
Valerio STERZI

GREThA, CNRS, UMR 5113
Université de Bordeaux

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Signaux et propriété des brevets académiques

Résumé
Bien que dans plupart des pays les professeurs d’université soient légalement obligés de divulguer leurs inventions au bureau de transfert de technologie de leur université, ce dernier n’a le plus souvent pas de pouvoir réel permettant de faire respecter cette règle. Nous introduisons ici un modèle qui endogénéise la décision d’une professeure d’une forme de transfert pour son idée. Si elle ne divulgue pas l’idée au bureau de transfert de technologie, elle doit faire face seule, à la fois à la difficulté de trouver un bon appariement pour sa technologie et à l’information incomplète de l’entreprise sur la qualité de son idée. Elle peut cependant, signaler cette qualité à l’entreprise sélectionnée à un coût qui est décroissant avec la qualité. Nous trouvons quatre types d’équilibre en stratégies pures de ce jeu de signaux. En les prenant tous en considération, le modèle prédit que la prise de propriété intellectuelle par l’entreprise des brevets académiques est associée avec une qualité plus importante du brevet, une forte expérience du professeur dans le transfert et une expérience plus faible du bureau de transfert de technologie. Nous estimons le modèle et confirmons ses prédictions sur un échantillon original de 1,260 paires brevet-professeur construit sur données du Royaume Uni. Une attention particulière est portée à la possibilité de plusieurs formes de causalité inverse par laquelle le type de propriétaire du brevet pourrait affecter la qualité du brevet.

Mots-clés : Jeux de signaux, brevets académiques, transfert de technologie.

Signaling and the Ownership of Academic Patents

Abstract
Although in most countries, professors are legally obligated to disclose their inventions to their university’s technology transfer office, the latter often does not have the real authority to enforce this rule. We here introduce a model that endogenizes a professor’s decision of a form of transfer for her idea. If she does not disclose the idea to the transfer office, she still faces, on her own, both the difficulty of identifying a good match for her technology with a company and the incomplete information of the company on the quality of her idea. She can, however, signal that quality to the company at some cost which is decreasing with quality. We find four types of pure strategy equilibria of this signaling game. Taking these four types of equilibria into account, the model predicts that the company ownership of academic patents are associated with higher patent quality, greater inventor experience in technology transfer, and lower technology transfer office experience. We estimate the model and confirm its predictions on an original sample of 1,260 patent-professor pairs built on UK data. Specific attention is paid to the control of various forms of potential reverse causality of the type of patent applicant on patent quality.

Keywords: signaling game, academic patents, technology transfer.

JEL: O31, O34

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Nicolas Carayol\(^\circ\,\circ\)\(^2\) and Valerio Sterzi\(^\circ\)\(^3\)

\(^\circ\) GREThA, Université Bordeaux IV - CNRS
\(^\circ\) Observatoire des Sciences et Techniques, Paris

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\(^2\) Nicolas Carayol, Université Bordeaux IV, GREThA - CNRS, Avenue Leon Duguit, F-33608 Pessac Cedex. Tel: +33-556844051. Observatoire des Sciences et Techniques, 21 Boulevard Pasteur, F-75015. Email: nicolas.carayol@u-bordeaux4.fr

\(^3\) Valerio Sterzi, Université Bordeaux IV, GREThA - CNRS, Avenue Leon Duguit, F-33608 Pessac Cedex. Tel: +33-556844051. Email: valerio.sterzi@u-bordeaux4.fr
1 Introduction

The basic rationale of the Bayh Dole reform in the US and similar university technology transfer reforms around the world consists of giving universities the right to retain property generated from government funded research because they are suspected to be the most efficient level at which to establish and manage the transfer of academic inventions to companies. Most research universities have now established their own technology transfer office (hereinafter *tto*), the main duty of which is to manage the transfer interface between the university and companies. Nowadays, the *tto*’s activity clearly constitutes a significant contribution to the technological leadership of developed nations. For instance, in the 2011 edition of the AUTM US Licensing Activity Survey, respondents reported up to 38,600 active licenses and options with nearly 4,900 new licenses executed that year.

There are two well identified problems that any transfer institution faces and, for each one, some arguments support the view that a university *tto* is indeed well suited to manage the transfer. The first problem is the information asymmetry over invention quality: the technology providers usually have much more information on the quality of their ideas. Several recent contributions have highlighted that an intermediary agency, such as the *tto*, may help to reduce the information asymmetry between inventors and investors by identifying new inventions and guaranteeing a minimum quality of the transferred invention. Hoppe and Ozdenoren (2005), in a static model, and Macho-Stadler et al. (2007), in a dynamic context, show the advantage of having a *tto* which pools inventions from several labs. In particular, the latter paper argues that the *tto* is able to build a reputation over time which contributes to mitigating the information asymmetry problem between scientists and firms. Considering a repeated game under imperfect information (the *tto* observes the quality, while the firm does not), the *tto* is indeed essential to the creation of a market for technology, especially where the total innovative activity of the university is large enough but where each research laboratory is too small to build a reputation by itself. To build a reputation, the *tto* has to shelve some lower quality disclosures, raising the firms’ belief
of expected quality.

The second problem a transfer institution must deal with is the matching of technology with a specific industrial and commercial use. In many domains, search costs are very high and even the organization of auctions to sell these technologies may be complicated, thus efficient searches must often be performed by professionals. Academics usually do not know the real potential uses of their discoveries and, in turn, do not know which firms are potentially interested. Considerable time and effort is therefore necessary to identify firms willing to acquire specific intellectual property rights from university inventions (Elfenbein, 2007). These search costs are likely to be mitigated by the tto which, because of specialization and a lower opportunity cost of time, is characterized by a lower cost of search. Hellmann (2007) specifically deals with the matching problem between inventors (scientists) and investors (firms) and theoretically shows that scientists have an incentive to delegate all search activities to the tto under the assumption that the tto has superior knowledge in identifying which firms can make use of the scientists’ discoveries.

Although these are convincing arguments, which show that the university ttos may perform technology transfer well, ttos are however not the only medium for technology transfer. As has been frequently highlighted, faculty members are not in an ivory tower and many professors build strong relationships with companies throughout their career, which may create the conditions for the emergence of a “gray market” for inventions (Link et al. 2007, Markman et al., 2008). Of course, in most universities and countries, and this is the case of the UK, scientists are legally obligated to disclose their inventions to the tto. However, scientists seem to have strong bargaining power over the tto. Anecdotal evidence shows that even though the tto often knows about patents that took the “back door”, they have little to no real power to fight against established faculty members. Thus scientists may bypass their tto despite the fact they are formally obliged to disclose their inventions to it.\footnote{See Kenney and Patton (2009) for an illuminating discussion on the inventor-tto relationship.} The tto director seems to have only formal authority rather
than real authority (Aghion and Tirole, 1994). As a matter of fact, the existence of a “gray market” for inventions is now empirically well documented. Markman et al. (2008), using a random sample of 54 US universities listed in the 1999-2000 edition of the Association of University Technology Managers (AUTM), found that 42% out of 3,200 academic inventors bypassed their institution at least once. Similarly, Thursby et al. (2009) using a sample of 5,811 US academic patents, found that 26% of them were assigned solely to firms rather than to the faculty member’s university. Lissoni et al. (2008) show that these figures are even sharper for some Continental Europe countries where the majority of academic patents are owned by the business sector (61% in Sweden, 72% in France and 81% in Italy). In the present paper, we show that UK lies in between the US and the Continental Europe figures with nearly 50% academic patents own by companies. These evidences highlight a third problem faced by any tto, namely that of attracting the academic inventions to the technology transfer process it manages. Though the institutional proximity of the ttos with the professors probably significantly contributes to upper-bound the share of inventions that take the back door, the professors seem to be in the position to choose a different way of transferring their technologies.

In this paper we attempt to theoretically and empirically investigate the transfer of academic inventions (and their consequences) in this more complex context, that is when ttos represent only one way of performing the transfer. Taking into account the empirical evidence, we develop a model which explicitly considers the possibility for academic scientists to sell their ideas directly to the market (thus bypassing the tto). However, in this situation, the faculty still has to personally face the two technology transfer issues identified above: high search costs and information asymmetry on the quality of their ideas. We model search costs by simply assuming that faculty members sample only one company to which to propose their inventions from among the ones they already know from previous experience. To mitigate the information asymmetry on the quality of its invention vis-à-vis the sampled company, the faculty is assumed to play first and to have the possibility of signaling the quality of their idea to that company. As in traditional
signaling models, this signal is costly and the cost decreases with the quality of what is signaled: here it is assumed that it is easier to convince the potential investor of the utility of the patent when it is of good quality. Once the signal is sent, the faculty makes a proposal to the company that takes the form of a fixed fee to receive, which is assumed to be the only possible contract in this situation. If the company accepts the proposal, the intellectual property is given to the company and the game ends with a patent filed by the company. If it refuses the proposed deal, the university retains the rights over the technology and the university sells an exclusive license through a Vickrey auction organized by the tto.

We find four types of Perfect Bayesian Equilibria of this game: two types of pooling equilibria and two types of separating equilibria. In the pooling equilibria, both the faculty with the high quality idea and the one with the low quality idea go to the tto, or they both go to the company. In one type of separating equilibria, both faculty members go to the company while the faculty with the high quality idea signals herself. In the other separating equilibrium, the (signaled) high quality idea is patented by the company and the low quality idea goes to the tto. The requirement that equilibria should respect the intuitive criterion (Cho and Kreps, 1987) partially rules out the multiplicity of equilibria, in such a way that the predictions of our model concerning the relation between the quality of ideas and patent ownership are completely clarified. Indeed, one of the most striking predictions of our theoretical model is that good ideas are more likely to bypass the tto. Our model also predicts that the patentable ideas invented by the faculty members who have a greater ability to find a good match on their own, which we proxy with patenting experience, have a greater chance of being owned directly by firms. Finally, the model suggests that more experienced, and thus more efficient (Jensen et al., 2003), ttos attract more inventions.

To estimate our model and its striking predictions, we exploited a sample of 1,260 UK patent-professor pairs corresponding to EPO patent applications made between 1990 and 2002. The baseline estimations of our theoretical model confirmed that university ownership is associated with higher patent quality (measured by patent citations), greater inventor patenting experience
and lower tto experience. We also developed specific empirical strategies to deal with the potential reverse causality of the type of ownership (company or university) on patent quality. Two specific reverse causality phenomena (exploitation and consulting) were first taken into consideration by excluding self-citations at the applicant level and by controlling for patent originality, as suggested by Thursby et al. (2009). In order to deal with other potential forms of reverse causality, we also developed an IV approach in which patent quality is instrumented by the quality of the previous patent invented by the same academic inventor and the size of the inventor’s team. Our results prove the robustness of our first estimations.

The remainder of the paper is organized as follows. Section 2 lays out the theoretical model, equilibria and empirical strategy, Section 3 presents the data and the econometric model, Section 4 presents the results and Section 5 concludes.

2 A model of signaling and patent ownership

In this section we introduce the signaling model, present the equilibria of the game and propose an estimation strategy.

2.1 The ownership game

We model academic technology transfer as a game involving a professor (p), a sampled private company (c) and the technology transfer office (tto). We assume first of all that the professor gets an idea that she considers as having a potential commercial application. She then has the possibility of choosing between two paths for the transfer of this technology: i) to sell her idea directly to a company she knows (possibly from past experience), or ii) to disclose it to the tto and let it manage the transfer process. In the latter situation, the inventor discloses the invention to the university which is assumed to always retain the intellectual property rights and the game ends with a university-owned patent. In the former situation, the inventor leaves the property rights to the company and the game ends with a company-owned patent.
We assume that the expected commercial value $\omega$ of a patentable idea is a function of its intrinsic scientific value $v$ (which can be seen as a probability of success) and the capacity $q$ of the firm to transform the idea into large commercial returns through its incorporation into a marketable technology. Of course, the two dimensions are complementary and we propose the following simple specification:

$$\omega = v \cdot q.$$  

(1)

One of the basic premises of our model is that $v$ is private information known only to the scientist. Here $q$ is common knowledge, however this assumption could be relaxed without significantly changing the results. For the sake of simplicity, we will also assume that $v \in V = \{v_h, v_l\}$, where $v_h > v_l > 0$. The objective prior probabilities shared by all companies on the distribution of $v$ are described by: $\Pr(v = v_l) = p = 1 - \Pr(v = v_h)$. The expected $v$ is noted as $\langle v \rangle = pv_l + (1 - p)v_h$.

The academic scientist can exert a signaling effort $e$ which produces a signal, noted as $s$. It is not certifiable and is only observed by the sampled company (other companies cannot observe it). These efforts may consist of several meetings, including their preparation, that the faculty must hold to convince the company of the quality of her idea. A natural assumption is that it is easier to convince the company of the utility of an invention when it is of good quality. Of course, the signal has no effect on the intrinsic scientific value of idea $v$. Thus the effort needed to provide a certain signal $s$, is also a function of $v$: $e(s, v)$. The standard and natural assumptions are that the marginal cost of signaling is decreasing with the quality of the idea, increasing with the signal and the cross derivative is also negative: $e'_v < 0, e'_s > 0$ and $e''_{vs} < 0$. In practice here, we will use the following functional form for the signaling technology:

$$e(s, v) = s/v.$$
gain of the scientist is given by:

\[ u_a(s, v) = F - e(s, v), \]

with \( F \) the fixed fee which is assumed to be the only feasible contract. The expected payoffs of the company, provided an agreement is reached, are:

\[ \pi_a = \sum_{v \in V} v \cdot \mu(s, v) \cdot q - F, \]

where \( \mu(s, v) \) denotes the posterior belief of the sampled company in the value of idea \( v \) having observed signal \( s \).

The other way to commercialize the idea is through the university’s tto. Once the idea is disclosed to the tto, it retains intellectual property rights and organizes a Vickrey auction for an exclusive license, and the expected returns of the scientist are given by:

\[ u_{na}(s, v) = \alpha \delta \langle v \rangle q_{tto} - e(s, v), \]

where \( \alpha \) is the share of the sale price which goes to the scientist (with a share of \( 1 - \alpha \) going to the institution). The parameter \( \delta \) is the discount factor which translates as the fact that going to the tto may take more time than making a deal with the sampled company. The quality of the second highest quality company that the tto is able to contact and convince to participate in the auction is \( q_{tto} \). For the sake of simplicity, we assume here that the initial company is either never sampled by the tto, or it never proposes the best offer. Therefore, the opportunity cost of accepting the offer is null: \( \pi_{na} = 0 \). Moreover, none of the bidders could observe signal \( s \) and evaluate the value of the idea at its mean \( \langle v \rangle \). The highest bidder is the one which has the highest capacity \( \bar{q} \geq q_{tto} \). He bids \( \langle v \rangle \bar{q} \) and pays \( \langle v \rangle q_{tto} \).

The timing of the game (summed up in Figure 1) is as follows:

- A faculty gets an idea and observes its quality \( v \in \{v_H, v_L\} \).
- She samples the most suitable company known personally and considers its quality \( q \).
• Then, she decides to exert a degree of personal effort $e$ with the intention of convincing that company of the quality of her idea. The signal $s$ produced is observed only by the company.

• The faculty proposes a fixed compensation $F$ to be paid by the company in exchange for the property rights.

• The proposal is accepted or rejected by the company: $d \in \{1, 0\}$.

• If an agreement is reached, the fixed fee is paid, the company obtains the property rights to the idea and each party receives the payoffs associated with this result. Otherwise, the scientist goes to the tto, which retains the property rights, contacts several companies and organizes a Vickrey auction to provide an exclusive license (or even to sell such property rights). Finally, it gives the scientist a share of the price paid (that was fixed before the game started).

Figure 1: Timing of the game.
2.2 Strategy profiles and equilibria

The game described above is a signaling game in which the informed agent typically plays first and has the opportunity to send a (costly) message $s$ that may or may not reveal its type ($v$). Here, once this message is sent, the first player (the faculty) can again make a take-it-or-leave-it offer to the company in the form of a fixed fee $F$ to be received in exchange for the property rights. The second player (the sampled company) merely makes an acceptance or rejection decision $d \in \{1, 0\}$, having observed signal $s$ and proposition $F$. A pure strategy profile of this game is thus: $((s, F) | v ; d | (s, F))$. Mixed strategies are not allowed.

A system of beliefs of the uninformed agent is given by $(\mu (s, v))_{s \in \mathbb{R}^+, v \in V}$ with $\mu (s, v) \geq 0$ and $\sum_{v \in V} \mu (s, v) = 1, \forall s$. A weakly perfect Bayesian equilibrium of this game is characterized by a strategy profile and a system of beliefs $((s^*, F^*) | v ; d^* | (s, F); (\mu (s, v))_{s \in \mathbb{R}^+, v \in \{v_H, v_L\}})$ in which the two equilibrium strategies are the best responses to each other, also given the beliefs of the uninformed player which are consistent with the equilibrium strategies of the informed player.

Depending on the values of the parameters, separating or pooling equilibria can arise. As shown below, for separating and pooling equilibria, two slightly different equilibria can arise.

2.2.1 Separating equilibria

Two forms of separating equilibria can occur, depending on whether the faculty with the low quality idea prefers to make a deal with the company or to go to the tto.

In the first type of separating equilibrium, both the faculty with the high quality idea and the faculty with the low quality idea prefer to make a deal with the initial company rather than to leave the intellectual property to the tto. This happens whenever the low quality scientist prefers to make a deal with the sampled company $q$ rather than leave the property rights to the tto. Although the two agents make a deal with the company, the faculty with the high quality idea signals its quality, allowing her to make a better deal with
the company. The faculty with the low quality idea sends no signal. The faculty with the high quality idea proposes to receive $F^* (v_h) = v_h \cdot q$, while the faculty with the low quality idea proposes to receive a fee $F^* (v_l) = v_h \cdot q$. The company accepts the offer if $v_l q \leq F^* \leq v_h q$ and $s^* = q v_l (v_h - v_l)$ and when $F \leq v_l q$. The equilibrium strategies are formally described below.

**Separating Equilibria 1.**
- $s^* (v_h) = s^L \in [q v_l (v_h - v_l), q v_h (v_h - v_l)]$ ; $s^* (v_l) = 0$
- $F^* (v_h) = q v_h$ ; $F^* (v_l) = q v_l$
- $d^* = \begin{cases} 1 & \text{if } F \leq q v_h \text{ and } s = s^L \\ 1 & \text{if } F \leq q v_l \text{ and } s \neq s^L \\ 0 & \text{otherwise} \end{cases}$
- $\mu (s, v_h) = 1 - \mu (s, v_l) = \begin{cases} 1 & \text{if } s = s^L \\ 0 & \text{otherwise} \end{cases}$

The following lemma describes the conditions under which Separating Equilibria 1 hold.

**Lemma 1** *Separating Equilibria 1 (SE1) hold if $q v_l > \alpha \delta q _ {tto} \langle v \rangle$.*

There is a second type of separating equilibria in which only the faculty with the high quality idea chooses to make a deal with the company rather than to leave the intellectual property to the tto. The scientist with the low quality idea prefers to leave the intellectual property to the tto as the maximum fixed fee that she obtain from the company is lower than what the scientist would get from the tto. According to the model, the scientist with the low quality idea will propose a high fixed fee to the sampled company that will be rejected by the company. The faculty with the high quality idea signals this quality, allowing her to make a better deal with the company. The faculty with the low quality idea sends no signal and leaves the intellectual property to the tto. The equilibrium is given by:
Separating Equilibria 2.

- \( s^* (v_h) = s^l \in [v_l (qv_h - \alpha \delta q_{tto} \langle v \rangle), v_h (qv_h - \alpha \delta q_{tto} \langle v \rangle)] \); \( s^* (v_l) = 0 \)
- \( F^* (v_h) = qv_h; F^* (v_l) > qv_l \)
- \( d^* = \begin{cases} 1 \text{ if } F \leq qv_h \text{ and } s = s^l \\ 1 \text{ if } F \leq qv_l \text{ and } s \neq s^l \\ 0 \text{ otherwise} \end{cases} \)
- \( \mu (s, v_h) = 1 - \mu (s, v_l) = \begin{cases} 1 \text{ if } s = s^l \\ 0 \text{ otherwise} \end{cases} \)

The conditions under which Separating Equilibria 2 hold are given in Lemma 2.

**Lemma 2** Separating Equilibria 2 (SE2) hold if \( qv_l < \alpha \delta q_{tto} \langle v \rangle \leq qv_h \).

### 2.2.2 Pooling equilibria

Two types of pooling equilibria exist according to the professor’s expected returns from the tto. Along the path of the first type of pooling equilibria (PE1), both types of ideas go to the company. Along the path of the second type of pooling equilibria (PE2), both types of ideas go to the tto. Lemmas 3 and 4 tell us that at least one PE1 occurs when the professor’s returns from the tto are low, while at least one PE2 occurs when these returns are high.

**Pooling Equilibria 1.**

- \( s^* (v_h) = s^* (v_l) = \hat{s} \in [0, v_l (\langle v \rangle - v_l)] \)
- \( F^* (v_h) = F^* (v_l) = q \langle v \rangle \)
- \( d^* = \begin{cases} 1 \text{ if } F \leq q \langle v \rangle \text{ and } s = \hat{s} \\ 0 \text{ otherwise} \end{cases} \)
- \( \mu (s^*, v_h) = 1 - \mu (s^*, v_l) = \begin{cases} 1 - p \text{ if } s = s^* \\ 0 \text{ otherwise} \end{cases} \)

**Lemma 3** There exists at least one Pooling Equilibrium 1 (PE1) if \( \alpha \delta q_{tto} \langle v \rangle \leq q \langle v \rangle \).
Pooling Equilibria 2.

- \( s^* (v_h) = s^* (v_l) = \bar{s} \in [0, qv_l (\alpha \delta q_{tto} \langle v \rangle - v_l)] \)
- \( F^* (v_h) > q \langle v \rangle ; \ F^* (v_l) > q \langle v \rangle \)
- \( d^* = \begin{cases} 
1 & \text{if } F \leq q \langle v \rangle \text{ and } s = \bar{s} \\
0 & \text{otherwise}
\end{cases} \) (PE2)
- \( \mu (s^*, v_h) = 1 - \mu (s^*, v_l) = \begin{cases} 
1 - p & \text{if } s = s^* \\
0 & \text{otherwise}
\end{cases} \)

**Lemma 4** There exists at least one Pooling Equilibrium 2 (PE2) if \( \alpha \delta q_{tto} \langle v \rangle \geq q \langle v \rangle \).

### 2.3 Synthesis and Empirical strategy

#### 2.3.1 Multiplicity of equilibria

Let us write \( \bar{\theta} = \alpha \delta q_{tto}, \) the expected returns of the faculty using the technology transfer process managed by the \( tto \). Depending on \( \bar{\theta} \), either one or two types of equilibria hold simultaneously:

- If \( \theta < qv_l \), then SE1 and PE1 hold. In these two types of equilibria, both faculties with the high and low quality ideas reach an agreement with the sampled company.

- If \( qv_l < \bar{\theta} < q \langle v \rangle \), SE2 and PE1 hold. Then, the faculty with the high quality idea reaches an agreement with the company in both equilibria. The behavior of the faculty with the low quality idea varies from one type of equilibrium to the other: she goes with the company in PE1 but prefers to go with the \( tto \) in SE2.

- If \( q \langle v \rangle < \bar{\theta} < qv_h \), SE2 and PE2 hold. Then, the behavior of the faculty with the low quality idea is invariant from one type of equilibrium to the other. Only the behavior of the faculty with the high quality idea differs: in SE2, she goes with the company while she prefers to go with the \( tto \) in PE2.

- If \( qv_h < \bar{\theta} \), only PE2 holds in which both faculties choose the \( tto \) transfer process.
The conditions under which the four types of equilibria described above hold are synthesized in Table (1). It is apparent that we have two forms of multiplicity of equilibria: within types and between types. The first form of multiplicity of equilibria is not really an issue for us since it does not modify ownership. The second, however, is more stringent when $qv_l < \bar{\theta} < qv_h$. In the following subsection, we will show that the intuitive criterion (Cho and Kreps, 1987) is sufficient to rule out undesirable multiplicity of equilibria.

<table>
<thead>
<tr>
<th>Equilibria</th>
<th>$\bar{\theta} = \alpha \delta \langle v \rangle q_{tto}$</th>
<th>$qv_l$</th>
<th>$q \langle v \rangle$</th>
<th>$qv_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE1 PE1</td>
<td>$c_{py}$</td>
<td>$c_{py}$</td>
<td>$c_{py tto}$</td>
<td>$tto$</td>
</tr>
<tr>
<td>PE1 SE2</td>
<td>$c_{py}$</td>
<td>$c_{py tto}$</td>
<td>$tto$</td>
<td></td>
</tr>
<tr>
<td>SE2 PE2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.3.2 The intuitive criterion

Weakly perfect Bayesian equilibria may rely on unreasonable beliefs off the equilibrium path. Cho and Kreps (1987) introduced a refinement, the intuitive criterion, which demands that off-equilibrium beliefs should interpret any deviation given the signaling content it potentially embodies. The intuition behind the intuitive criterion is that following a sender’s deviation (in this case, the professor), the receiver (the sampled company) should put a zero probability on that agent being of a type such that his equilibrium payoffs are greater than any payoff he could get from the deviation, provided the receiver plays his best response to the deviation (given his beliefs). Cho and Kreps (1987) show that the intuitive criterion rules out all pooling equilibria and keeps only the most efficient separating equilibrium in a single-crossing signaling model with two types. As a direct consequence, here only the most efficient of Separating Equilibria 1 and of Separating Equilibria 2 remain. Pooling Equilibria 1 never survive and Pooling Equilibria 2 survive
only when \( \bar{\theta} > qv_h \). In this case, it is easy to see that no agent wants to deviate by signaling itself to the sampled company because the returns from the company cannot be greater than the expected returns of following the technology transfer process managed by the \( tto \).

Table (2) presents the equilibria that still hold. It is is clear here that the faculties with the high and low quality ideas adopt contrasted behaviors in the equilibrium paths when \( qv_l < \bar{\theta} < qv_h \). This provides a key insight that will clarify the predictions of the model, in particular concerning the relation between the quality of ideas and patent ownership. This is the purpose of the next subsection.

Table 2: Weakly perfect Bayesian equilibria that respect the intuitive criterion.

<table>
<thead>
<tr>
<th>( \bar{\theta} = \alpha \delta \langle v \rangle q_{tto} )</th>
<th>( qv_l )</th>
<th>( q \langle v \rangle )</th>
<th>( qv_h )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibria</td>
<td>SE1</td>
<td>SE2</td>
<td>SE2</td>
</tr>
<tr>
<td>( v = v_h )</td>
<td>cpy</td>
<td>cpy</td>
<td>cpy</td>
</tr>
<tr>
<td>( v = v_l )</td>
<td>cpy</td>
<td>tto</td>
<td>tto</td>
</tr>
</tbody>
</table>

### 2.3.3 Empirical strategy

Let us assume now that the returns from the auction organized by the \( tto \) are uncertain to the observer but known by the faculty, so that the professor’s expected returns from the auction are now given by \( \theta = \bar{\theta} + \varepsilon \) where \( \varepsilon \) is normally distributed with zero mean. The dichotomic variable \( y \) that will be our dependent variable, takes the value one if the property goes to the company, and zero otherwise. From the point of view of the observer, the probability that a given invention goes to the company is now:

\[
\Pr(y = 1) = \Pr(\theta + \varepsilon < qv_l) + \Pr(qv_l < \theta + \varepsilon < q \langle v \rangle) \times 1_{\{v = v_h\}} + \Pr(q \langle v \rangle < \theta + \varepsilon < qv_h) \times 1_{\{v = v_h\}}
\]  
\[
+ \Pr(q \langle v \rangle < \theta + \varepsilon < qv_h) \times 1_{\{v = v_h\}}
\]  

(5)
where \(1_{\{\cdot\}}\) denotes the indicator function which equals one if the condition in brackets is verified and zero otherwise. After some simple recombinations, it comes that the probability that an academic patent is owned by a company if:

\[
Pr(y = 1) = F\left(q (v_h - v_l) \cdot 1_{\{v=v_h\}} + qv_l - \theta\right),
\]

where \(F\) denotes the normal cumulative distribution function. The nice thing with the empirical estimations presented below is that we have some proxies for each of the right hand variables. The quality of the idea (and the patent) can be measured ex post by using patent citations, the capacity \(q\) of the company can be also proxied by the patenting experience of the scientist, assuming that the greater her experience in patenting, the higher the number of companies she knows and thus the higher the quality of the company she samples, and \(\theta\) can also be proxied by the experience of the \(tto\) (essentially through \(q_{tto}\)), which has been highlighted as being of great importance in previous studies.

The immediate empirical analogue of equation (6) is given by :

\[
Pr(y = 1) = F\left(\alpha_1 q (v_h - v_l) \cdot 1_{\{v=v_h\}} + \alpha_2 qv_l - \alpha_3 \theta\right).
\]

At some point, we will be interested in separating the effects of the three variables that are interacted with, and we will also perform the following regression :

\[
Pr(y = 1) = F\left(\beta_1 q + \beta_2 v - \beta_3 \theta + \beta_4 D\right),
\]

with \(D\), a vector of covariates, including technological field dummies (capturing in particular \(v_h - v_l\)) and other control variables (including potentially university dummies).

### 3 Data description and variables

In this section, we focus on the description of the data and the construction of the variables used.
3.1 Sample and data collection

Data on UK academic inventors have been collected using a methodology similar to the one described in Lissoni et al. (2008). Our database is the result of a merge of the PATSTAT database containing all EPO applications filed between 1978 and 2002 and the Research Assessment Exercise (RAE) 2001 database containing data on 60,672 academic researchers employed by British universities and higher education institutions in 2001. Individual information is limited to university department (or research center) of affiliation, discipline, surname and initials of the first name.

Academic inventors were identified in four steps. First, on one side, only inventors of European patents whose last patenting year was not before 1994 and not later than 2002 were considered. On the other side, only individual scientists from the RAE database in Medicine, Biological Sciences, Pharmacy and Chemistry, Physics and Mathematics and Engineering Sciences and Electronics were considered. Second, the two databases were merged by surname and first name initials. This procedure resulted in 9,009 potential UK academic inventors. Third, web searches were performed to collect more detailed information in order to compare professors’ full names with inventors’ full names. After any false matches were deleted, we still had 5,005 potential UK academic inventors. Fourth, further web searches were performed to collect professors’ email addresses which led to a list of 2,588 professors’ emails. These professors were then asked by email to confirm or infirm via a web interface their inventor status of the EPO patent applications associated with their names that were invented between 1990 and 2001. Out of the 998 answers received, 625 researchers confirmed at least one invention. The comparison of respondents versus non-respondents showed no significant differences in each of professors’ disciplines.\footnote{Tests are not included in the paper due to space constraints but are of course available from the authors.}

Altogether, these 998 inventors reported 1,376 academic patent applications applied for at the European Patent Office (EPO) when they were working in a UK university. Table (3) breaks down these patents by the
type of their first applicant(s).\textsuperscript{3} Since our focus is on the allocation of ownership between universities and companies, we consider only the following categories: companies, universities, co-applications between universities and companies, and others.\textsuperscript{4} Around 6\% of academic patents were applied for by at least two assignees of different types. Furthermore, most of the time, one university is listed among the co-applicants and in this case, if so and if in addition no company is involved, the patent is categorized as university owned in Table (3). Simultaneously, the patents assigned to companies in this table only involve company applicants. Despite this conservative rule, Table (3) shows that almost 50\% of academic patents in the sample are owned only by firms. This figure puts the UK in between European continental countries, which usually report more than 70\% of company owned academic patents (see Lissoni et al. 2008, Czarnitzki et al. 2012), and the US where the same figure falls to 25\% of academic patents assigned only to companies (Thursby et al. 2009). The high percentage of patents owned by firms in the UK may be surprising as scientists have been legally obligated to disclose their inventions to the tto since 1977.\textsuperscript{5}

\textsuperscript{3}The applicant of the first filing may differ from the data we retrieved from the PATSTAT database, in case of a later change of ownership. In this case, there is a possibility that some patents which appear as owned by companies were initially owned by public institutions or preferences. To take into account this possibility, we individually checked all patents owned by companies according to the PATSTAT database. We found that 5\% of these patents were originally owned by universities and for this reason we categorized them as university assigned.

\textsuperscript{4}The patents in this category include patents assigned to government and PROs (Public Research Organizations), to physical persons, or to specific institutions as the British Technology Group (BTG), which was a public organization operating as a brokerage agency in support of universities until its privatization in 1993. For robustness, all regressions were reperformed when BTG patents are re-categorized as university owned patents whenever the priority year was before the privatization, and as company owned patents otherwise. All results remain the same (available upon request).

\textsuperscript{5}For further discussion on university IPR regulations in Europe, see Geuna and Rossi (2011).
Table 3: Frequency and number of academic patents by ownership type.

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td>48.1</td>
<td>662</td>
</tr>
<tr>
<td>University</td>
<td>38.1</td>
<td>524</td>
</tr>
<tr>
<td>Univ and Cpny</td>
<td>3.5</td>
<td>48</td>
</tr>
<tr>
<td>Others</td>
<td>10.3</td>
<td>142</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>1376</td>
</tr>
</tbody>
</table>

3.2 Dataset and variables

In order to build the final dataset, and since we are interested in the reasons why some academic patents are assigned to firms while others are assigned to universities, we kept the 1,186 patent applications which were owned either by a firm only or by at least one university but which then were not co-owned by any company. The units of observation consist of patent-professor pairs, resulting in 1,260 observations. Single patent applications may appear more than once if they have been invented by more than one academic inventor in the sample. The dichotomic dependent variable $y_i$ is the applicant type: one for university and zero for company only. Let us now describe the construction of the explanatory variables.

For what concerns the measurement of patent value ($v$), the ideal data would consider the value of licensed patents estimated at the time of the ownership decision. However, such data are not easily obtained therefore we prefer to use a forward looking measure which is the number of forward citations received by the patent, as previous studies have shown that these are highly correlated with the value of the invention and with the perceived importance by the inventors themselves (Trajtenberg 1990; Harhoff et al. 1999; Harhoff and Reitzig 2004; Hall et al. 2005). More precisely, the quality of the focal patent is proxied by the number of forward citations (excluding self-citations at the inventor level) in the first three years after the patent priority date ($PatQual_i$ where $i$ refers to the patent-professor pair).

The capacity of the company to exploit the professor’s idea ($q$) is simply approximated by the patenting experience of the focal professor, assuming
that the capacity to find a good match on one’s own is enhanced by previous invention experience. For each patent-professor pair \( i \), the focal professor patenting experience (\( ProfExp_i \)) is measured by the logarithm of the number of EPO patent applications applied for by the focal academic inventor before the invention date of focal patent \( i \).

The expected returns of the faculty using the technology transfer process managed by the tto (\( \theta \)) is approximated by the tto patenting experience. For each patent, we consider the number of patents applied for by each university where the academic inventor was working at the time of application. In order to retrieve this information, we relied on curriculum vitae and affiliations from publications.\(^6\) The variable \( UnivExp_i \) is the logarithm of the cumulative number of EPO patents owned by the university (taken at the time of the focal patent invention) where the focal professor was employed at the time of the focal patent.

We also propose to capture the idea that finding a company may also depend on the local demand side. We suggest that the higher the patenting experience of the private sector in the professor’s local environment and technological sector, the higher the probability that she will leave the intellectual property to a company. We thus build the control variable \( FirmsExp_i \) which is the number of patents (in logs again) in the same technological field as the focal patent and in the same county as the professor’s residence address, applied for by firms before the patent application year.\(^7\) Finally, in some models we also include a control for the broadness of the invention, such as the logarithm of the number of claims (\( Claims_i \)).

Table (4) shows summary statistics. All variables are expressed as their logarithm plus one.

\(^6\)Unfortunately, for 61 patent-professor pairs we were not able to add this information.  
\(^7\)Due to some missing information on inventors’ addresses, we are unable to compute the \( FirmsExp \) variable for 126 patent-professor pairs.
Table 4: Summary statistics on the sample of patent-professor pairs.

<table>
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<tr>
<th></th>
<th>obs.</th>
<th>mean</th>
<th>sd</th>
<th>min</th>
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</thead>
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<td>0.83</td>
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<td>ProfExp</td>
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<td>0</td>
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<td>UnivExp</td>
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<td>1.34</td>
<td>0</td>
<td>5.66</td>
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<td>4.44</td>
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<td>FirmExp</td>
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<td>2.24</td>
<td>0</td>
<td>7.24</td>
</tr>
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</table>

4 Estimation issues and results

4.1 Baseline estimations

The simplest way to assess the patent ownership decision is to rely on a binary framework such as a probit model. According to the theoretical model, we regress patent, professor and university characteristics on a binary assignment variable which equals one if the patent is assigned to a firm and zero if it is assigned to a university. Patents assigned to Others are excluded from the analysis. Since the observations in the model consist of patent-professor pairs, academic inventors may appear multiple times in the data, therefore we used clustered standard errors to control for potential dependence among the error terms.

Probit coefficient estimates and their level of significance are presented in Table (4.1). In each model, we included year dummies which control the influence of the year in which a patent has been applied for at the EPO. We also considered technological dummies (OST 30) which account for the fact that some fields, due to their intrinsic characteristics, might be more likely to be assigned to one or other type of organization, and university dummies to control for the university technology transfer policy.

Column (I) presents the estimated coefficients of equations deriving from model (7). Low ($v_l$) and high ($v_h$) patent quality are the 25th and 75th percentiles in the population of all UK patents in the year and technological field of the focal patent. As the quality is proxied by forward citations up to 3 years after the filing year and the distribution of citations is highly
skewed, the $25^{th}$ percentile of the distribution in each year and sector has zero citations, that is $v_l = 0$. Hence, technological field impacts are captured only by $v_h$. When also replacing each parameter with its empirical counterpart and indexing for patent-professor pair $i$, equation (7) then simplifies in:

$$\Pr(y_i = 1) = F(\alpha_1 \cdot PatQual_i \cdot ProfExp_i \cdot v_{hi} - \alpha_3 \cdot UnivExp_i).$$

(9)

Column (II) corresponds to the same model, to which technological field dummies are added. Columns (III) to (VI) display the estimated coefficients of (8), which becomes

$$\Pr(y_i = 1) = F(\beta_1 \cdot PatQual_i + \beta_2 \cdot ProfExp_i - \beta_3 \cdot UnivExp_i + \beta_4 D).$$

(10)

when replacing all explaining variables by their empirical proxies. The vector of controls $D$ includes technological field dummies in the model presented in Column (IV), it also includes $Claims_i$ and $FirmsExp_i$ in the model of Column (V) and university dummies in Column (VI).\(^8\) Finally, it should be noted that year dummies are included in all models.

In each probit model, the signs of the coefficient estimates are as expected from the theoretical discussion and significantly different from zero. This supports our view that patent ownership is a rational decision by professors, who consider the costs and benefits of bypassing the tto. First of all, higher quality ideas are more likely go directly to firms, as the signaling cost for the inventor is lower. In particular, when university dummies and control variables are taken into account (column VI), the effect of patent quality is substantial and significant at the 99% level. For a one-unit change in the number of citations, the model implies a 3.1% increase in the probability that the patent is owned by a firm.\(^9\)

As also expected, we find that the higher the professor’s patenting experience, the greater the probability that the academic patent is owned by a company. In more detail, the increase of the company ownership probability

\(^8\)Patent-professor pairs are lost in the last two columns since we are missing information on professors’ location and university affiliation at the time of the patent.

\(^9\)All marginal effects are calculated at mean values of the explanatory variables and are available from the authors.
with respect to one more patent previously applied for by the professor is 6.9%. As expected again, more experienced tto\(_{i}\)s are more likely to attract inventions. However, university patenting experience (UnivExp\(_{i}\)) is no more significant after controlling for university dummies (Column VI). This suggests that our measure of tto experience captures more variation between universities than within the same university. Interestingly, the model including university dummies considerably increases the explanatory power, with pseudo R-squares above 0.15.

Lastly, no effect was found for the two controls included in the last two models (Columns V and VI). As found in Thursby et al. (2009), the number of claims is negatively but not significantly associated with company ownership. The coefficients for FirmsExp\(_{i}\) are never significant, suggesting that the local market for technology is not the main target of the academic inventions.

### 4.2 Endogeneity of patent quality

The main result of our baseline models indicates that better patents are more likely to be associated with the corporate ownership of academic patents. We are however concerned that the estimates presented in the previous section could be biased due to a reverse causality issue. On the one hand, patent ownership can depend on patent quality as the theoretical model describes, however, on the other hand, patent quality can also be due to the type of applicant. Since we use the number of patent citations as proxy of patent quality, our quality measure could reflect not only patent characteristics but also the applicant’s characteristics.

We propose three complementary methods to address this issue. The first two, presented in the next subsection, relate to some specific views on the way reverse causality arises (exploitation and consulting) and offer practical and simple solutions. The third relies on an instrumental variable approach that is presented in the second subsection.
Table 5: Baseline models, Probit estimates.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
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<td>$PatQual_i$</td>
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<td>0.0871*</td>
<td>0.115**</td>
<td>0.142***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0458)</td>
<td>(0.0462)</td>
<td>(0.0479)</td>
<td>(0.0502)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ProfExp_i$</td>
<td>0.174***</td>
<td>0.169***</td>
<td>0.165***</td>
<td>0.174***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0656)</td>
<td>(0.0635)</td>
<td>(0.0641)</td>
<td>(0.0659)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$UnivExp_i$</td>
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<td>-0.158***</td>
<td>-0.187***</td>
<td>-0.170***</td>
<td>-0.177***</td>
<td>0.0618</td>
</tr>
<tr>
<td></td>
<td>(0.0495)</td>
<td>(0.0475)</td>
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<td>(0.0476)</td>
<td>(0.0497)</td>
<td>(0.190)</td>
</tr>
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<td>$Claims_i$</td>
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</tr>
<tr>
<td>$PatQual_i \cdot ProfExp_i \cdot v_{ih}$</td>
<td>0.0576**</td>
<td>0.0497*</td>
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<tr>
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<td>(0.0280)</td>
<td>(0.0267)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
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<td>Univ. dummies</td>
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<td>No</td>
<td>Yes</td>
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<td>Yes</td>
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<td>1260</td>
<td>1260</td>
<td>1134</td>
<td>1046</td>
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<tr>
<td>Pseudo $R^2$</td>
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<td>0.057</td>
<td>0.088</td>
<td>0.090</td>
<td>0.167</td>
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</table>

Clustered (at professor level) standard errors in parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Year dummies are included in all models. The dependent variable is equal to one if the patent applicant is a company, and zero if it is a university. Patents applied for by individuals, BTG and PROs are not considered.
4.2.1 Two specific reverse causality phenomena: exploitation and consulting

First of all, a patent of a given quality may have a different number of citations due to the applicant’s exploitation. It is possible that the problem associated with the patented idea under scrutiny originates from the company. When a company has an important problem to address but no resources and competences to deal with, it may be interested in contacting academic professors. In this case, the company moves first and may require to retain the assignment of any potential resulting intellectual property. These patents may also be more likely to be highly cited by further patents invented at the company itself, which is likely to keep following this line of inquiry. To remove this possible exploitation effect, we exclude all citations coming from the same applicant when computing patent quality. We thus propose a new patent quality variable, $\text{PatQualnocomp}_i$, which is the logarithm of the number of citations received excluding self-citations at the applicant level of the focal patent.

The second issue is related to the possibility again that the company moves first but then selects a number of professors and employs them in a consulting activity. Thursby et al. (2009) suggest that patents derived from consulting activities should be less basic than those assigned to universities and propose to add a variable capturing the originality of the scientific idea. As they suggest, we rely on the patent originality measure developed by Trajtenberg et al. (1997), a Herfindhal based index reflecting the dispersion of citations made by the patent across patent classes, which is calculated as follows:

$$\text{Originality}_i = 1 - \sum_j s^2_{ij},$$  \hspace{1cm} (11)

where $s_{ij}$ is the share of $i$’s backward citations falling into the technological class $j = 1, ..., 30$ (which we measure by the OST 30 classes).\(^{10}\) A score of 0 indicates that all backward citations fall into one technological class,\[^{10}\]

\(^{10}\)For patents without backward citations in the search report, Originality would be unspecified. We adopted the following stratagem: whenever a patent does not cite a patent as reference, we consider the same patent as cited.
while a score close to one indicates citations to many classes. In this light, a patent is considered more original when it cites prior art from many different technological classes.

4.2.2 The instrumental variable approach

To control for more generic causes of reverse causality, we also propose an instrumental variable approach. Acknowledging that patent quality can still be determined by type of ownership, patent quality estimates can thus still be biased. As an exogenous source of variation for each patent quality (now proxied by $PatQual_{incomp}$) we use both the quality of the previous patent invented by the same academic inventor and the size of the inventor’s team.

In more detail, we use the number of citations of the previous patent invented by the professor under consideration as a first instrument for patent quality. The idea is that the previous patent is not correlated with the ownership of the actual patent, rather it is correlated with the quality of the actual patent. The issue in doubt here is whether the exogeneity condition holds, as one could argue that if personal contacts are important in the ownership decision and do not change quickly over time, the actual patent ownership might be correlated with the previous one. In order to improve estimation precision, as an alternative and additional instrument, we also consider the number of inventors listed in the patent. We argue that this indicator is related to patent quality but not to patent ownership, as shown by Sapsalis et al. (2006). Our identification assumptions are that previous patent quality and the number of inventors listed in the patent are related to patent quality but not to patent ownership. If this is the case, our instruments turn out to be valid and satisfy the orthogonal assumption.

Since one of the instruments refers to the characteristics of previously applied for patents, we lose 691 patent-professor pairs, because i) 314 academic inventors (out of the 571 identified) invented only one patent and are

---

11Sapsalis et al. 2006, in a sample of 400 biotech Belgian patents, found that the average size of the inventor’s team was the same (about 3.3) for university and company owned patents. Our data show a slightly higher number of inventors for company patents (3.5 versus 3.2).
thus excluded, and ii) all of the first patent-professor pairs relate to the first invention of an academic inventor are excluded. Hence, in the IV-probit estimation, the identification is achieved by the inclusion of the number of inventors and the previous patent quality that record the exogenous change in the actual patent quality in the first-stage regression. A probit model on patent ownership that incorporates the instrumented patent quality as an explanatory variable will then be estimated in the second stage.

4.2.3 Results

The results are given in Table (6). The model in column (I) is analogous with the model of column (IV) of Table (4.1) with the inclusion of the variable $Originality_i$ as a further control variable of patent ownership. In column (II), we exclude all citations coming from the same patent applicant in the dependent variable (now $PatQualnocomp_i$). In column (III), we show the results of the two step IV-probit for the restricted sample of 637 patent-professor pairs; finally column (IV) shows the probit estimates for the restricted sample used for the IV-probit.

Interestingly, we find in column (I) of Table (6) that the estimated coefficient of $Originality_i$ is negative, as in Thursby et al. (2009), but not significant, while quality and professor patenting experience are still positively and significantly related to patent ownership. In particular, the increase of company ownership probability with respect to the number of citations is 5.1%. Moreover, these results are robust to the exclusion of self-citations at the applicant level (Column II). Patent quality is still significant (at 95%) and the magnitude of its effect does not vary too much with respect to previous estimates (increases of company ownership probability by 4.3%).

The IV-estimates are displayed in column (III). The Amemiya’s generalized Least Squares (AGLS) probit estimation\footnote{We use the ‘ivprobit, twostep’ routine in Stata.} (Newey 1987) that we use amounts to estimating OLS on patent quality and then using the predicted values in the ownership probit model. The AGLS estimator produces a consistent estimation of the standard errors and may perform better than MLE
<table>
<thead>
<tr>
<th></th>
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<td>-1.066***</td>
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<td>-0.113</td>
<td>-0.427**</td>
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<td>(0.0273)</td>
</tr>
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</table>

Technology dummies: Yes, Yes, Yes, Yes

University dummies: No, No, No, No

Observations: 1134, 1134, 637, 637

Wald (p-value): 0.005

Amemiya-Lee-Newey (p-value): 0.49

Weak instr. F-test (p-value): 10.92

Pseudo R²: 0.092, 0.090, 0.117

Clustered (at professor level) standard errors in parentheses in columns I-II.

* p < 0.10, ** p < 0.05, *** p < 0.01. Year dummies are included in all models.

The dependent variable is equal to one if the patent applicant is a company, and zero if it is a university. Patents applied for by individuals, BTG and PROs are not considered.

The instruments for patent quality are the number of patent inventors and the patent quality of the previous patent invented by the same professor.
in a smaller sample when instruments are weak (Adkins, 2010). However, IV Probit estimation with clustered standard errors is not feasible in this case. A possible solution is to use the clustered bootstrap method, which creates resamples of the observed data by dyads (patent-inventor) and then estimates by IV Probit method. Unfortunately this method does not give us reliable estimates since one or more parameters cannot be estimated in too many replications.

To test whether patent quality is endogenous to the ownership regression, the Wald test of endogeneity (Wooldridge 2001) was performed. The null hypothesis corresponds to the exogeneity case of the regressor under scrutiny. The Wald test computations (bottom of Table (6), Column III) lead us to reject the null hypothesis of exogeneity of the regressor and therefore justifies the use of an IV-estimation. Then, in order to test whether the two instruments are valid, the Amemiya-Lee-Newey test was used. The null hypothesis is that the instruments are jointly valid, that is, they are uncorrelated with the error term in the structural equation and the instruments are correctly excluded from the estimated equation. With the two aforementioned instruments for patent quality (the number of patent inventors and the patent quality of the previous patent), Table (6) (column III) shows that the Amemiya-Lee-Newey minimum chi square p-value is 0.49\(^{13}\) which leads to the non rejection of the null hypothesis. Finally, regarding the performance of our instruments, the F-test for weak instruments is equal to 10.92 and this may be a warning of potential weak instruments. However, the first-stage results (not displayed here to save space but available from the authors) indicate a significant partial correlation of our instruments with patent quality (at the 95% significance level for the first instrument and 99% for the second).

The IV estimates of patent quality coefficients are significant and much greater than the ones observed in the baseline model run on the same sample (column IV). This suggests that baseline probit coefficients of patent quality are downward biased. Interestingly, the coefficient of professor patenting experience decreases (and is no longer significant) once controlling for endo-

\(^{13}\)Calculated using the iv-probit and overid modules for Stata.
geneity and this may suggest that part of the effect of patent quality was captured by professor experience in the baseline model. University patenting experience still matters on the patent ownership. Finally, patent characteristics (Originality and Claims) turn out to be significant and negatively associated with company ownership.

5 Conclusions

While many scholars in law, sociology, and economics explore which entities should and could optimally own inventions that arise out of federal funding (Kenney and Patton 2009, 2011), in this article we highlight the strategic behaviour of academic inventors in the commercialization of their invention even when by law they are called to leave the ownership to their university.

More in detail, we theoretically and empirically investigate the transfer of academic inventions by considering the tto as facilities that are only one way of commercializing university inventions. In this perspective, university researchers may try to commercialize their inventions on their own, thus bypassing the tto, and directly face the problems of information asymmetry over invention quality and of matching with a specific industrial and commercial use. In order to address the first problem we argue that they may signal the quality of their idea to a sampled company. Facing the second problem, we hypothesize that professors can rely on their previous patenting experience. The structure of the pure strategy equilibria of the signaling model leads to a positive relation between patent quality and company ownership.

Empirical tests of our theoretical model provide support for existence of a gray market for academic inventions with academic scientists going outside the controls of the university administration. Our empirical analysis relies on a sample of more than twelve hundred pairs of UK academic patents applied for between 1990 and 2001 at the European Patent Office. Simple statistics show that almost 50% of them were assigned to a company. Probit estimates show that company ownership is indeed associated with higher patent quality. Moreover, as predicted by the model, greater inventor patenting experience and lower tto experience are also associated with company own-
ership. Results are robust to the inclusion of other patent characteristics (such as the number of claims and technological class dummies) as controls. Finally, potential reverse causality problems are taken into consideration. We find that the removal of self-citations at the applicant level and the control of patent originality do not change the results. In addition, the results of an IV approach in which patent quality is instrumented by the quality of the previous patent invented by the same academic inventor and the size of the inventor’s team proves the robustness of our results.

These findings may be of interest for technology policy designers and technology transfer managers. They support the idea that the tto are only one of the possible ways of technology transfer among which university professors can arbitrate. Their CEOs should develop specific contractual strategies to avoid their facility being bypassed by professors, in particular when their inventions are suspected to be of higher quality, a line of investigation that is straightforwardly suggested by our results: late entrant universities in technology transfer could inflate royalty shares to inventors as a means to balance their lack of experience in technology commercialisation; highly experienced professors in patenting could be proposed to receive a higher share as well (or an improved service), and less decreasing returns to the professor with the amount generated by the invention could be examined.

Our analysis is not without limitations. It would be interesting to bring our basic model of ownership decision closer to the reality by putting it in a broader perspective, for example by considering at which stage of the academic R&D process firms and professors contact each other, or by empirically analysing the role played by royalty and license fees proposed by their tto on the strategic behaviour of academic scientists.

6 References


Quarterly Journal of Economics 102, 179-221.


Markman, G.D., Gianiodis, P.T., Phan, P.H., 2008. Full-time faculty or


7 Appendix

7.1 Proofs

7.1.1 Proof of Lemma 1 (Separating Equilibria 1)

The proof of Lemma 1 goes in three steps: first, it examines the incentives of the faculty member with the high quality idea to deviate from her equilibrium strategy (i), before turning to the case of the faculty with the low quality idea (ii) and finally to the sampled company (iii).

(i) Let us first consider the case of the faculty with the high quality idea. In SE1, she incurs a signaling cost \( e(s^*(v_h), v_h) \) that fully reveals her quality \( v_h \). In this equilibrium, the company’s expected payoffs observing such a signal are \( \pi_a = v_hq - F^*(v_h) \), since its (fully consistent) posterior beliefs lead to \( \mu (s^*(v_h), v_h) = 1 \), and \( \mu (s^*(v_l), v_l) = 0 \). Therefore, the faculty with the high quality idea proposes an agreement to the company that saturates its participation constraint \( F = qv_h \), and her utility becomes:

\[
u_a (s^*(v_h), v_h) = qv_h - e(s^*(v_h), v_h).
\] (12)

Provided the signal is not less than \( qv_l (v_h - v_l) \) (to prevent the faculty with the low quality idea from also signaling), the faculty sets it no greater than \( qv_h (v_h - v_l) \) and her utility is such that:

\[
u_a (s^*(v_h), v_h) \geq qv_l.
\] (13)

The scientist could deviate by simultaneously modifying the signaling efforts and the agreement proposal made to the sampled company. It is trivial to see that a higher signal would lead to a lower utility, as increasing signaling efforts would be costly while not allowing the scientist to obtain a better deal. A lower signal \( s < s^*(v_h) \), would lead to not signaling type, and obviously, in this case, her utility would simply be the same as the faculty with the low quality idea in this equilibrium, since she then has no incentive to provide any signaling efforts at all. The faculty’s payoffs become equal to either the payoffs in the technology transfer process managed by the \( tto \) if she does not
modify her proposition to the sampled company, that is $\alpha \delta q_{tto} \langle v \rangle$, or $qv_l$ if she formulates a proposal that saturates the sampled company’s participation constraint. Here, as stated in Lemma 1, we have $qv_l > \alpha \delta q_{tto} \langle v \rangle$, and thus the faculty with the high quality idea would simultaneously modify her proposal to the company to obtain an agreement. Hence, the scientist with the high quality idea would not have any incentive to deviate by reducing her signaling costs whenever $u_a(v_h, s^*(v_h)) \geq qv_l$, which turns to be always verified as equation (13) states.

(iii) Let us now consider the incentives of the faculty with the low quality idea to deviate.

In the equilibrium path, sustaining a null signaling cost $e(0, v_l) = 0$ and proposing an agreement that saturates the participation constraint of the sampled company, provides her with a utility of:

$$u_a(0, v_l) = qv_l. \quad (14)$$

The faculty could deviate by choosing a signal that would mimic the scientist with the high quality idea. Then, her signal would be: $s(v_l) = s^*(v_h) = s^L \geq qv_l(v_h - v_l)$. The efforts associated with such a signal for the scientist with the low quality idea are $e(s^L, v_l) \geq q(v_h - v_l)$. While also proposing an agreement to the company that is the same as a faculty with a high quality idea, her utility is such that:

$$u_a(s^*(v_h), v_l) \leq qv_l. \quad (15)$$

Hence, the scientist with the low quality idea will never have an incentive to deviate. The scientist with the low quality idea could also deviate from the equilibrium strategy by choosing a different fee to the sample company. A lower fee would trivially bring less and a higher fee would lead to a refusal from the company in this equilibrium, which would push the faculty to disclose the idea to the $tto$ and obtain $u_{na} = \alpha \delta q_{tto} \langle v \rangle$, which is lower than $qv_h$ (we recall that the assumption here is that $\alpha \delta q_{tto} \langle v \rangle < qv_l$ and that by assumption $v_l < v_h$).

(iii) Finally, let us consider the case of the sampled company.
The company could deviate from the equilibrium strategy by accepting the offer either when $s < s^L$ and $F \leq v_h q$, when $s \geq s^L$ and $F > v_h q$, or even when $F > q v_l$ and $s < s^L$, or when $F \leq q v_l$ and $s \geq s^L$. It is trivial to see that it would not be better off in any of these cases.

### 7.1.2 Proof of Lemma 2 (Separating Equilibria 2)

In the equilibrium path of any SE2, only the faculty with the high quality idea prefers to make a deal with the sampled company rather than disclosing her idea to the tto. Lemma SE1 tells that these equilibria stand whenever $q v_l < \alpha \delta q_{tto} \langle v \rangle < q v_h$.

The proof of Lemma 1 goes in three times: first, it examines the incentives of the faculty with the high quality idea to deviate from her equilibrium strategy (i), before turning to the case of the faculty with the low quality idea (ii) and lastly to the sampled company (iii).

(i) Let us first consider the case of the faculty with the high quality idea. In SE1, she incurs a signaling cost $e(s^*(v_h), v_h)$ that fully reveals her quality $v_h$. In this equilibrium, the company’s expected payoffs observing such a signal are $\pi_a = v_h q - F^*(v_h)$, since its (fully consistent) posterior beliefs are such that $\mu(s^*(v_h), v_h) = 1$, and $\mu(s^*(v_l), v_l) = 0$. Therefore, the faculty with the high quality idea proposes an agreement to the company that saturates its participation constraint $F = q v_h$, and her utility becomes:

$$u_a(s^*(v_h), v_h) = q v_h - e(s^*(v_h), v_h).$$  \hspace{1cm} (16)

In any of these equilibria, the faculty with a high quality idea sets a signal no greater than $q v_h (q v_h - \alpha \delta q_{tto} \langle v \rangle)$ and her utility is then such that:

$$u_a(s^*(v_h), v_h) \geq \alpha \delta q_{tto} \langle v \rangle.$$ \hspace{1cm} (17)

The faculty with the high quality idea could deviate by simultaneously modifying the signaling efforts and the agreement proposal made to the sampled company. It is trivial to see that a higher signal would lead to a lower utility as increasing signaling efforts would be costly while not allowing the scientist to obtain a better deal. A lower signal $s < s^*(v_h)$, would lead to the
faculty not signaling her type, and obviously, in this case, her utility would simply be the same as the faculty in this equilibrium, since she then has no incentive to provide any signaling effort at all. The faculty’s payoffs become equal to either the payoffs in the technology transfer process managed by the tto if she does not modify her proposition to the sampled company, that is \( \alpha \delta_{q_{tto}} \langle v \rangle \), or \( qv_l \) if she formulates a proposal that saturates the sampled company’s participation constraint. Here, as stated in Lemma 2, we have \( qv_l < \alpha \delta_{q_{tto}} \langle v \rangle \), and thus the faculty with the high quality idea would simultaneously modify her proposal to leave the IP to the TTO. Hence, the scientist with the high quality idea would not have any incentive to deviate by reducing her signaling costs whenever \( u_a (s^*(v_h), v_h) > qv_l \), which turns out to be always verified (as stated in Equation 17).

(ii) Let us now consider the incentives of the faculty with the low quality idea to deviate.

In the equilibrium path, sustaining a null signaling cost \( e(0, v_l) = 0 \), and proposing an agreement greater than the participation constraint of the sampled company \( (F^*(v_l) > qv_l) \) in order to leave the IP to the TTO, provides her with a utility of:

\[
 u_a (0, v_l) = \alpha \delta_{q_{tto}} \langle v \rangle .
\]  

(18)

The faculty could deviate by choosing a signal that would mimic the scientist with the high quality idea. Then, her signal would be: \( s(v_l) = s^*(v_h) = s^L \geq v_l (qv_h - \alpha \delta_{q_{tto}} \langle v \rangle) \). The efforts associated with such a signal for the scientist with the low quality idea are such that \( e(s^L, v_l) \geq (qv_h - \alpha \delta_{q_{tto}} \langle v \rangle) \).

While also proposing an agreement to the company that is the same as a faculty with a high quality idea, her utility (by deviating from the equilibrium strategy) becomes:

\[
 u_a (s^*(v_h), v_l) \leq \alpha \delta_{q_{tto}} \langle v \rangle .
\]  

(19)

Hence, the scientist with the low quality idea would not have the incentive to deviate. The scientist with the low quality idea could also deviate from the equilibrium strategy by choosing a different fee to the sample company. A fee lower than the firm participation constraint in the low quality inventor case would trivially bring less (the company would accept the offer and in
that case the scientists would obtain \( v_h q < \alpha \delta q_{\text{TTO}} \langle v \rangle \), and a higher fee would lead to the same outcome of the equilibrium (as the company would not accept the proposal and the scientist would end up with the TTO outcome).

(iii) Finally, let us consider the case of the sampled company.

The company could deviate from the equilibrium strategy by accepting the offer either when \( s < s^L \) and \( F \leq v_h q \), when \( s \geq s^L \) and \( F > v_h q \), or even when \( F > q v_l \) and \( s < s^L \), or when \( F \leq q v_l \) and \( s \geq s^L \). It is trivial to see that it would not be better off in any of these cases.

7.1.3 Proof of Lemma 3 (Pooling Equilibria 1)

In the equilibrium path of any pooling equilibrium 1, both scientists with the high quality and low quality ideas prefer to make a deal with the sampled company rather than disclosing their idea to the tto.

The proof of Lemma 3 goes in three steps: first, it examines the incentives of the faculty with the high quality idea to deviate from her equilibrium strategy (i), before turning to the case of the faculty with the low quality idea (ii) and finally to the sampled company (iii).

(i) Let us first consider the case of the faculty with the high quality idea.

In PE1, she incurs a signaling cost \( e(s^*(v_h), v_h) = \frac{s^*}{v_h} \leq \frac{v_h}{v_h} (\langle v \rangle - v_l) \). In this equilibrium, the company’s expected payoffs observing such a signal are \( \pi_a = \langle v \rangle q - F^*(v_h) \), since its posterior beliefs remain unchanged: \( \mu(s^*(v_h), v_h) = 1 - p \), and \( \mu(s^*(v_l), v_l) = p \). Therefore, the faculty with the high quality idea proposes an agreement to the company that saturates its participation constraint \( F = \langle v \rangle q \), and her utility becomes such that:

\[
    u_a(s^*(v_h), v_h) = \langle v \rangle q - e(s^*(v_h), v_h) \geq \langle v \rangle q - \frac{v_l}{v_h} (\langle v \rangle - v_l)
\]

(20)

The scientist with the high quality idea could deviate by simultaneously modifying the signaling efforts and the agreement proposal made to the sampled company. It is trivial to see that a higher signal would always lead to a lower utility, as increasing signaling efforts would be costly while not allowing the scientist to obtain a better deal. It is also trivial to see that
by asking for a lower fee, the scientist will end up with a payoff that is lower than the equilibrium. On the other side, by asking for a higher fee ($F^d > \langle v \rangle q$), the scientist will end up with the $tto$ outcome, as the sampled company would reject the offer in equilibrium: in this case, the associated gross payoff would be $\alpha \delta q_{tto} \langle v \rangle$ instead of $\langle v \rangle q$. Thus, she would not have the incentive to deviate to the extent that $\langle v \rangle q \geq \alpha \delta q_{tto} \langle v \rangle$. If the low quality idea professor deviates by reducing efforts, then the optimal deviation is to provide no effort and the net payoffs become null. Thus the professors do not deviates this way if $\langle v \rangle q \geq \frac{\hat{s}}{v_l}$.

(ii) Let us now consider the incentives of the faculty with the low quality idea to deviate.

The same reasoning above applies to the faculty with the low quality idea. In the equilibrium path, sustaining a signaling cost $e(s^*(v_l), v_l) = \frac{\hat{s}}{v_l}$, and proposing an agreement that saturates its participation constraint $F = \langle v \rangle q$, her utility becomes:

$$u_a(0, v_l) = \langle v \rangle q - e(s^*(v_l), v_l) = \langle v \rangle q - \frac{\hat{s}}{v_l} \quad (21)$$

It is trivial to see that the scientist will not have the incentive to deviate to the extent that $\langle v \rangle q \geq \alpha \delta q_{tto} \langle v \rangle$ (as stated in Lemma 3) and $\langle v \rangle q \geq \frac{\hat{s}}{v_l}$.

(iii) Finally, let us consider the case of the sampled company.

The company could deviate from the equilibrium strategy by accepting the offer when $F > \langle v \rangle q$. It is trivial to see that, in this case, it would not be better off as the expected profit would be negative.

Compiling (i) and (ii) and (iii), we see that there is always at least one Pooling Equilibrium 1 as soon as $\langle v \rangle q \geq \alpha \delta q_{tto} \langle v \rangle$, the one where the on the equilibrium path signal $\hat{s} = 0$. Thus completes the proof of Lemma 3.

7.1.4 Proof of Lemma 4 (Pooling Equilibria 2)

In the equilibrium path of all second pooling equilibria, both the scientists with the high quality and low quality ideas prefer to disclose their idea to the $tto$ rather than make a deal with the sampled company.
Let us first consider the case of the faculty with the high quality idea. In PE2, she does incur a signaling cost \( e(s^*(v_h), v_h) = \frac{s}{v_h} \). In this equilibrium, the company’s expected payoffs observing such a signal are \( \pi_a = \langle v \rangle q - F^*(v_h) \), since its (fully consistent) posterior beliefs lead to \( \mu(s^*(v_h), v_h) = 1 - p \), and \( \mu(s^*(v_l), v_l) = p \). In the equilibrium, the faculty with the high quality idea proposes an agreement to the company that is greater than its participation constraint \( F^*(v_h) > \langle v \rangle q \) and her utility becomes:

\[
u_{na}(\bar{s}, v_h) = \alpha \delta qtto \langle v \rangle - e(s^*(v_h), v_h) = \alpha \delta qtto \langle v \rangle - \frac{s}{v_h}
\] (22)

The scientist with the high quality idea could deviate by simultaneously modifying the signaling efforts and the agreement proposal made to the sampled company. It is trivial to see that a higher signal would lead to a lower utility, as increasing signaling efforts would be costly while not allowing the scientist to get a better deal. It is also trivial to see that by asking for a fee that is not greater than the company’s participation constraint, the scientist will end up with the associated payoff of \( \langle v \rangle q \) instead of \( \alpha \delta qtto \langle v \rangle \). Thus, she will not have the incentive to deviate to the extent that \( \alpha \delta qtto \langle v \rangle > \langle v \rangle q \). If the low quality idea professor deviates by reducing efforts, then the optimal deviation is to provide no effort and the net payoffs become null. Thus the professors do not deviates this way if \( \langle v \rangle q \geq \frac{s}{v_h} \).

Let us now consider the incentives of the faculty with the low quality idea to deviate.

The same reasoning above applies to the faculty with the low quality idea. In the equilibrium path, sustaining a signaling cost \( e(s^*(v_l), v_l) = \frac{s}{v_l} \) and proposing an agreement to the company that is greater than its participation constraint \( F^*(v_h) > \langle v \rangle q \), her utility becomes:

\[
u_{na}(\bar{s}, v = v_l) = \alpha \delta qtto \langle v \rangle - \frac{s}{v_l}
\] (23)

It is trivial to see that the scientist will not have the incentive to deviate to the extent that \( \langle v \rangle q \geq \alpha \delta qtto \langle v \rangle \) and \( \langle v \rangle q \geq \frac{s}{v_l} \).

Finally, let us consider the case of the sampled company.
The company could deviate from the equilibrium strategy by accepting the offer when $F > \langle v \rangle q$. It is trivial to see that, in this case, it would not be better off as the expected profit would be negative.

Compiling (i) and (ii) and (iii), we see that there is always at least one Pooling Equilibrium 2 as soon as $q \geq \alpha \delta q_{\text{tto}}$, the one where the equilibrium path signal $\hat{s} = 0$ (as stated in Lemma 4).
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