Information gathering, innovation and growth

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2 March 2011

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This version: March 2, 2011

Abstract: In this paper we study the economic implications of IPR protection on corporate intelligence, R&D investment and economic growth. To accomplish this objective, we introduce trade secret and information leakage into a standard quality-ladder growth model and study the long-run implications of improving the privacy of firms' data. We find that reducing the set of practices of information gathering is more effective in protecting firms' privacy than strengthening trade secrets.

JEL classification: D9, K4, L5, O32

Keywords: Quality-improvement, R&D, information leakages, corporate intelligence, growth.

Acknowledgments: I wish to thank the Editor and an anonymous Referee for constructive criticism and suggestions. I am also grateful to Raouf Boucekkine, Antonio Minniti and Paul Segerstrom for helpful comments on earlier versions of this paper. Financial support from the Italian Ministry for the University and Scientific Research (PRIN-2008YYBH7L) is gratefully acknowledged. Any remaining errors are mine.

1 Introduction

The importance of R&D in technology-intensive sectors has been widely highlighted by the Schumpeterian theory (e.g. Grossman and Helpman (1991), and Aghion and Howitt (1992, 1998)). In this literature, patent law - or more generically, intellectual property rights (IPR) protection - plays a primary role in the process of economic development. Thanks to the granting of patents, firms establish a product's virtual everlasting monopoly, which allows entrepreneurs to recoup the enormous amounts of cash spent on R&D. Yet, it is quite a widespread belief that collecting and making use of some kind of information about competitors is as crucial an element as R&D for market leadership. However, not all the available practices of information gathering, often called *corporate intelligence*, are acceptable and many of them are often considered extreme forms of *industrial espionage* (or *spying*).

In this paper we present a dynamic general equilibrium model of R&D investment and corporate intelligence in which the latter takes the form of information gathering. Our research objectives are twofold. First, we are interested in studying the long-run effects of corporate intelligence on innovation and growth. Second, we are interested in building a tractable analytical framework to study the long-run implications of IPR protection on corporate intelligence, R&D investment and growth.

In order to plug information gathering into the standard Schumpeterian growth model, we introduce two main modifications to the standard Grossman and Helpman's (1991) quality-ladder scheme. The first modification consists in assuming that each R&D race is a two-stage activity, meaning that each R&D firm invests resources to discover the way to produce a higher quality product for first, and then tries to render the discovery useful for business purposes. In the meanwhile, firms do not patent the discovery and try to keep any confidential information regarding the new discovery secret from their competitors. The second modification consists in assuming that the trade secret is weakly protected, meaning that the IPR protection system does not provide enough protection against illegitimate practices of corporate intelligence. This assumption allows us to distinguish two different sources of information disclosure. The first source is the involuntary leakage of sensitive information due, for instance, to incidental disclosure by workers. The second source of information disclosure is related to the voluntary information gathering activity carried out by market rivals through costly corporate intelligence.

We find that a steady-state equilibrium with information gathering exists only to the extent to which the degree of IPR protection is not very high. Specifically, we find that when the economy starts with a degree of IPR protection that is high enough to discourage any form of corporate intelligence, the economy has no room for information gathering and works as a standard fully-endogenous growth model with quality innovation; in contrast, when the economy starts with a low degree of IPR protection, corporate intelligence becomes more attractive to firms and the economy has room for information gathering. When the latter occurs, we find that strengthening IPR protection - in terms of introducing a new scheme of protection for a firm's confidential data - leads to a permanent increase in the steady-state innovation rate but also to a permanent decrease in the steady-state level of per capita consumption expenditure.

Up to now, economic theory (especially on innovation, IPR protection and growth) has paid much more attention to imitation than information gathering, particularly that on technology transfer and North-South trade (e.g., Helpman (1993), Lai (1998), and Glass and Saggi (2002) among others)[1]. Cozzi (2001) represents the only exception in which alternative phenomena of misappropriation such as interim imitation and spying, along with their long-run implications for technological change and economic growth, are theoretically analyzed. Technically speaking, Cozzi (2001) builds a general equilibrium model of growth and spying to study the choice of being either a producer of new ideas or a spy. It finds that the existence of a positive espionage activity depends on the size of the population and that a larger population increases the equilibrium number of spies without affecting long-run growth.

This paper presents at least three drawbacks. Firstly, even though the steady-state equilibrium features a roughly constant rate of patenting, Cozzi's model features both a constant patents-per-researcher ratio and time-invariant innovative R&D employment. This result is not consistent with the empirical evidence provided by Jones (1995) and Kortum (1996), who show that the total amount of resources devoted to R&D in the most important industrial economies has grown dramatically in spite of the roughly constant rate of patenting. Secondly, in the presence of a growing population Cozzi's model predicts that the fraction of labor engaged in spying activities tends to grow without bounds, meaning that no steady-state equilibrium with spying exists because of the scale effect[2]. Finally, Cozzi is unclear about what spying is in his model. In the paper, in fact, he claims that he is calling spying "*an activity that contemplates both lawful and ethical searching for inspiration and illegal industrial espionage*" (see Cozzi (2001, p. 68)), which is equal to saying that spying consists of all those R&D activities other than innovation. We think this approach makes it difficult to disentangle what is the lawful practice

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[1] Closed economy models of growth with innovation and imitation usually do not pay much attention to the IPR-related aspects of imitation and copying. See, in particular, Rustichini and Schmitz (1991), Segerstrom (1991) and Mukoyama (2003).

[2] Parello (2005) uses a different approach to generate a non-explosive rate of espionage activity by introducing increasing difficulty in R&D along the lines suggested by Segerstrom (1998). He finds that in the long run the economy grows semi-endogenously and that any change in the structural parameters of the economy affects the steady-state growth rate of the economy only temporarily.

of information gathering from what is the result of an illegal activity of corporate espionage, thereby rendering Cozzi's model unsuitable for studying IPR issues.

Our model differs from Cozzi (2001) in at least two respects. First, our model plugs trade secrets into the standard quality-ladder model and focuses on information gathering rather than spying. Second, our model adopts a dilution scheme for R&D and generates a scale-invariant fully-endogenus growth process where all research activities, including forms of R&D other than pure innovation, do not depend on the scale of the economy.

Cozzi and Spinesi (2006) adopt a similar approach to ours to avoid explosive paths for industrial espionage. Nonetheless, our paper departs from Cozzi and Spinesi (2006) along at least two dimensions. On the one hand, our model does not need any restriction on the growth rate of population in order to generate a scale invariant rate of activity for corporate intelligence. On the other hand, the paper presents a different approach to modelling the firm's choice between innovation and an alternative form of R&D that consists in splitting the process of R&D investment into two stages: a first stage of creating ideas (pure innovation), and a second stage of refining of the ideas in which inventive firms competes with the corporate intelligence in making pure innovations useful for business purposes.

The outline of the paper is the following. Section 2 sets up the model and presents the main differences between it and a standard R&D-based growth model. Section 3 solves the model for the steady-state equilibrium and analyzes its long-run properties. Section 4 analyzes the steady-state equilibrium effect of stronger IPR protection. Section 5 discusses the main results of the model and tries to provide a possible policy interpretation of them. Finally, Section 6 concludes.

2 The model

2.1 Overview of the model

The industrial framework consists of a continuum of industries indexed by $\omega \in [0,1]$. In each industry ω, firms are distinguished by the quality of the products they produce, where $j(\omega,t)$ denotes the quality vintage (or *state of the art*) of industry ω at instant t. At time $t=0$, the state of the art of each industry is $j=0$ and only one firm knows how to produce the $j=0$ quality product.

To learn how to improve the state of the art, firms participate in innovative R&D races. In contrast to the basic Schumpeterian growth models of Grossman and Helpman (1991) and Aghion and Howitt (1992), we assume that each R&D race is a two-stage activity. In the first stage, firms invest resources to discover the way to produce the next quality rung $j+1$ and, if successful, use the trade secret in order to keep information secret. To simplify the analysis, we assume that keeping information secret is costless but also that there is a risk of leakage due to the incidental disclosure of sensitive information. In the second stage, firms try to render the discovery useful for business purposes through a refinement of the previous discovery. This refinement can be independently carried out either by the innovating firm (henceforth the author) or some rivals, whose main objective is to collect sensitive information through corporate intelligence, write down a marketable minor variation in competition with the author and then try to beat the author in a "race to the Patent Office" similar to that proposed by Cozzi (2001).

The probability that an author will win the race to the Patent Office is exogenously given, while the probability that a rival will win the race is endogenously given and depends on their intelligence effort. We assume that the winner of the "race to the Patent Office" becomes the only producer of the $j+1$ quality product, regardless of whether he is actually the author or not. We focus on the steady-state equilibrium in which all innovative activity takes place in the long run and in which innovation takes the form of improvements in the quality of products.

2.2 Preferences and technologies

The economy has a fixed number -normalized to one- of identical households that provide labor services in exchange for wages. Each household is modelled as a dynastic family, whose growing size is given by $L(t)=e^{nt}$ (with $L(0)=1$ and $n>0$).

The representative household chooses from a continuum $\omega \in [0,1]$ of products available at different quality levels. Perfect foresight of the future value of wages $w(t)$ and the rate of interest $r(t)$ implies that, for a given sequence of pairs $\{w(t), r(t)\}$, $t \in (0,\infty)$, the problem for the representative household is to choose a sequence of consumption which maximizes the discounted utility:

$$\max_{c} U \equiv \int_0^{\infty} e^{-(\rho-n)t} \log u(t)\, dt, \qquad \rho > n \tag{1}$$

subject to:

$$\begin{aligned} \log u(t) &\equiv \int_0^1 \log\left[\Sigma_j q_j(\omega,t)\, d_j(\omega,t)\right] d\omega && (2)\\ c(t) &\equiv \int_0^1 \left[\Sigma_j p_j(\omega,t)\cdot d_j(\omega,t)\right] d\omega && (3)\\ W(t)+A(t) &= \int_t^{\infty} c(\tau)\cdot e^{n\tau} e^{-[R(\tau)-R(t)]} d\tau && (4) \end{aligned}$$

Eq. (2) is the Cobb-Douglas specification of the consumption index, where $d_j(\omega, t)$ denotes the quantity consumed of a product of quality j produced in industry ω at time t and $q_j(\omega, t) \equiv \lambda^{j(\omega,t)}$ denotes the overall quality level of industry ω after $j(\omega, t)$ innovations, with $\lambda > 1$ measuring the size of quality improvements or quality jump.[3] Eq. (3) is the static budget constraint which assumes that in each instant of time t the per capita expenditure of the representative household, $c(t)$, must equate the value of all final goods consumed, where $p_j(\omega, t)$ denotes the price of a product of quality j produced in industry ω at time t. Finally, Eq. (4) is the intertemporal budget constraint which assumes that the sum of the household's discounted wage income, $W(t)$, and the present value of the representative household's financial assets, $A(t)$, must be equal to the discounted value of consumption, where $R(t) \equiv \int_0^t r(\tau)\, d\tau$ is the cumulative interest rate and $\dot{R}(t) = r(t)$ denotes the instantaneous interest rate at time t.

At each instant t, the representative household allocates expenditure to maximize the utility per person $u(t)$, given the prevailing market prices of each brand ω. Because of the separability of Eq. (1), the representative consumer's maximization problem can be solved in three steps. The first step is to choose the allocation of expenditure for each product across available quality levels. To solve this problem, the representative consumer allocates expenditure for each product at each instant to the quality level $j(\omega, t)$ offering the lowest quality-adjusted price, $p_j(\omega, t)/q_j(\omega, t)$. We assume that when quality-adjusted prices are the same for two products of different vintages, consumers only buy the higher quality product.

The second step consists in choosing the allocation of expenditure across existing brands $\omega \in [0, 1]$ by maximizing discounted utility (2) subject to (3). Given the Cobb-Douglas specification of the consumption index (2), solving this optimal control problem leads to the demand function for the product with the lowest quality-adjusted price in industry ω given by

$$d(\omega, t) = \frac{c(t)}{p(\omega, t)} \tag{5}$$

Finally, the third step is to choose the allocation of lifetime wealth across time by maximizing discounted utility (1), given Eqs. (3) and (4), and subject to the intertemporal budget constraint (4). The solution for this optimal control problem leads to the usual Euler equation

$$\frac{\dot{c}(t)}{c(t)} = r(t) - \rho \tag{6}$$

According to Eq. (6), higher market interest rates induce consumers to save more now and spend later, resulting in an increased growth rate of per capita consumption.

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[3] Because λ^j is increasing in j, (2) captures the idea that consumers like higher quality and also has the property that vertically differentiated products in a given industry substitute perfectly for one another once the appropriate adjustment is made for quality differences.

The manufacturing sector of the economy is imperfectly competitive. As in Grossman and Helpman (1991), a patent is needed to enter industries and produce the next higher-quality product. Once successful, production technology is the same across industries and one unit of general labor is required to produce one unit of output. The labor market is perfectly competitive and labor is the numéraire of the model. This means that firms have a common marginal cost of production equal to one.

We assume Bertrand price competition between leaders and followers. Since (5) presents unitary elasticity[4], innovation is always non-drastic and quality leaders can always drive competitors out of the market by underpricing followers. Indeed, with the follower charging a price equal to marginal cost, the quality leader earns the profit flow $\pi(t) = (1 - 1/\tilde{p})\, c(t)\, L(t)$ from charging the price $\tilde{p} \leq \lambda$ and zero profits otherwise. As a result, by setting price $\tilde{p} \leq \lambda$, each quality leader captures the entire industry market and will perform the same flow of sales equal to $D(t) = c(t)\, L(t)/\lambda$. Accordingly, all leaders have the same profit flow given by

$$\pi(t) = \left(1 - \frac{1}{\lambda}\right) c(t)\, L(t) \tag{7}$$

whereas all followers decide to stay in the market without producing.

2.3 The research sector

2.3.1 Research and development

To introduce new ideas, firms participate in stochastic R&D races aimed at discovering higher-quality final consumption goods. We assume free entry into each inventive R&D race and the existence of a common constant returns to scale technology available to all racers.

Any firm i that hires $\ell_i(\omega, t)$ units of labor (henceforth R&D workers) in industry ω at time t is able to introduce a useful idea to develop the next quality rung $j + 1$ with instantaneous probability (or Poisson arrival rate):

$$I_i(\omega, t) = \frac{\ell_i(\omega, t)}{b\delta(t)} \tag{8}$$

where $b > 0$ is a technology parameter and $\delta(t)$ is a R&D difficulty index which tells us how the state of technology evolves over time.

The $\delta(t)$ term in the denominator of (8) is adopted in order to rule out the scale effect property of the early vintage of R&D-based endogenous growth models -e.g. Romer (1990),

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[4] This is the result of the Cobb-Douglas specification adopted by the consumption index (2), which implies that the elasticity of substitution between every pair of product brands is equal to one. For an alternative approach with drastic innovation see, among others, Aghion and Howitt (1992, 1998) and Dinopoulos and Thompson (1998).

Grossman and Helpman (1991) and Aghion and Howitt (1992).[5] The specification adopted in this paper is the so-called PEG (Permanent Economic Growth) specification, which is given by:

$$\delta(t) = \kappa L(t) \tag{9}$$

where $\kappa > 0$ is an exogenous parameter. According to (9), as the population grows, $\delta(t)$ increases over time and innovating becomes more difficult. The specification adopted by (9) can be justified by saying that R&D difficulty is proportional to the size of the market because of organizational costs related to product distribution (Dinopoulos and Segerstrom (1999)).

2.3.2 Information gathering and corporate intelligence

Instead of setting up research labs, firms can invest resources in information gathering and corporate intelligence. Corporate intelligence consists of all those activities aimed at gathering relevant and up-to-date information about rivals' market activities, such as market research, product development plans, research and development, etc.

Any firm i that hires $s_i(\omega, t)$ units of labor (henceforth market researchers) in industry ω at time t is able to come up with a radical idea and modify it into the quality product $j+1$ with instantaneous probability (or Poisson arrival rate):

$$\sigma_i(\omega, t) = \frac{s_i(\omega, t)}{\mu \xi(t)}, \qquad \text{with } \xi(t) \equiv L(t) \tag{10}$$

where $\mu > 0$ is an exogenous technology parameter reflecting the degree of IPR protection in the economy and $\xi(t)$ is a difficulty index which tells us how difficult information gathering is as time goes by.

We interpret parameter μ as the "red line" separating what is acceptable and unacceptable practice of information gathering, whose level depends on the amount of information covered by the trade secret. The greater the set of information protected by every trade secret, the higher the value of μ and the higher the probability for the author to patent his own discovery. Consequently, μ can be seen as a measure of the degree of protection of a firm's confidential information.

The presence of the $L(t)$ term in the denominator of (10) can be justified in the following way. Any increase in the size of the population, $L(t)$, could potentially translate into either greater pure R&D or greater corporate intelligence, or both. If the size of corporate intelligence

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[5] Jones (1995) has persuasively criticized the empirical validity of this prediction by pointing out that several measures of R&D resources (such as R&D expenditure or the number of scientists and engineers in R&D) exhibit exponential growth in sharp contrast to the stationary per capita output and total factor productivity growth rates.

increases because of the increase in the size of the workforce, it will also reduce the chances of a worker finding an idea that has not yet been used for business purposes: the more corporate intelligence there is around, the less one single worker can gain from being ready to find ideas. This is a sort of *competition effect* which reduces the instantaneous probability that one worker will come up with the right idea because of the presence of a larger number of workers gathering information.[6]

2.3.3 The optimal R&D choice

In this section we outline the essential features of R&D investment. The problem for each firm is to decide whether to invest resources in either R&D or information gathering. Consider first the case in which firm i decides to do R&D by setting up a research lab. Once successful in introducing a radically new idea, the firm resorts to trade secrets protection and goes on to the second stage of R&D which consists in making the discovery useful for business purposes.

Trade secret protection does not preclude sensitive information outflowing from the firm due to both incidental disclosure and corporate intelligence. The leakage of the secret thus depends both on the technical complexity of hiding innovations and the strength of IPR protection. Following Franzoni and Denicolò (2004), we assume that the event of an incidental disclosure follows a Poisson process with an exogenous arrival rate equal to $\phi > 0$.

Let $v(\omega, t)$ denote the expected discounted profit for winning an R&D race in industry ω at time t. The author's probability of successfully modifying the first-stage innovation is the same across industries and given by the exogenous parameter α.[7] Since the "race to the Patent Office" takes place instantaneously, the prize of winning the race is given by:

$$\int_0^\infty \alpha e^{-(\alpha+\phi+\sigma)s} v(\omega, t)\,\mathrm{d}s = \frac{\alpha v(\omega, t)}{\alpha + \phi + \sigma}.$$

Next, the firm chooses the optimal labor input that solves the following maximization problem:

$$\max_{\ell_i} \left\{ \frac{\alpha}{\alpha + \phi + \sigma} v(\omega, t) \frac{\ell_i(\omega, t)}{b\delta(t)} - \ell_i(\omega, t) \right\}$$

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[6] Cozzi and Spinesi (2006) use a similar approach, the so-called *dilution effect*, to avoid explosive paths for the steady-state R&D investment. In contrast to our paper though, their model does not present any competition effect among spying, meaning that the incentive to carry out illegal corporate intelligence is not related to the abundance of spies in the economy.

[7] Note that the authors's winning rate α does not vary between industries. In a more general setting, cross-industry differences in this parameter may be the result of different industry-specific institutional settings of trade secret protection. In this paper we restrict our attention to analyzing the extent to which α is the same for all industries, leaving the analysis of cross-industry differences in the author's winning rate to future research.

Differentiation with respect to ℓ_i gives the following free-entry condition:

$$\frac{\alpha}{\alpha+\phi+\sigma} v(\omega,t) \begin{cases} \leq b\delta(t) & \text{if} \quad I_i(\omega,t)=0 \\ = b\delta(t) & \text{if} \quad I_i(\omega,t)>0 \end{cases} \tag{11}$$

The left-hand side of (11) is related to the benefits of becoming an Author, while the right-hand side is related to the cost of becoming an Author. Costs exceeding benefits would discourage any possible attempt to create breakthrough ideas, whereas benefits exceeding costs would lead to innovation at an infinite intensity. As a result, an equilibrium with a positive and finite rate of innovation requires (11) to hold with equality.

Observe that according to (11), each R&D firm allocates the same number of R&D workers to innovative tasks. So, in the rest of the analysis, we focus on a symmetric equilibrium where $\ell(\omega,t) = \Sigma_i \ell_i(\omega,t)$ is the industry-wide number of innovative R&D workers in industry ω at time t.

Consider now the case in which firm i decides to gather information by setting up a corporate intelligence system. The total arrival rate of sensitive information is given by the sum of the arrival rate of an incidental information disclosure ϕ and the arrival rate of information gathering $\sigma(\omega,t)$. The expected reward for the aggregate information gathering sector is:

$$\int_0^\infty (\phi+\sigma) e^{-(\alpha+\phi+\sigma)s} v(\omega,t)\,\mathrm{d}s = \frac{(\sigma+\phi) v(\omega,t)}{\alpha+\phi+\sigma}.$$

Consequently, the probability that the newly produced idea is caught by one information gathering firm equals $1/[\alpha+\phi+\sigma(\omega,t)]$[8] while the expected flow return of winning the race to the Patent Office is given by:

$$\frac{1}{\alpha+\phi+\sigma(\omega,t)} v(\omega,t) \frac{\ell(\omega,t)}{b\delta(t)}$$

As a result, firm i chooses its labor input to maximize its expected profits:

$$\max_{s_i} \left\{ \frac{1}{\alpha+\phi+\sigma(\omega,t)} \frac{\ell(\omega,t)}{b\delta(t)} v(\omega,t) \frac{s_i(\omega,t)}{\mu L(t)} - s_i(\omega,t) \right\}$$

Differentiation with respect to s_i gives the following free-entry condition:

$$\frac{1}{\alpha+\phi+\sigma(\omega,t)} \frac{\ell(\omega,t)}{b\delta(t)} v(\omega,t) \begin{cases} \leq \mu L(t) & \text{if} \quad \sigma_i(\omega,t)=0 \\ = \mu L(t) & \text{if} \quad \sigma_i(\omega,t)>0 \end{cases} \tag{12}$$

The left-hand side of (12) is related to the benefits of corporate intelligence while the right-hand side is related to the costs of corporate intelligence. Costs exceeding benefits would choke

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[8] As each information gathering firm has the same chance of finding ideas, the individual probability of being successful in finding a still not patented innovation is positive and described by density: $\left[\frac{\phi+\sigma(\omega,t)}{a+\phi+\sigma(\omega,t)}\right] / (\phi+\sigma(\omega,t)) = \frac{1}{a+\phi+\sigma(\omega,t)}$.

information gathering, whereas benefits exceeding costs would lead to information gathering at an infinite intensity. Hence, an equilibrium with a positive and finite rate of information gathering requires (12) to hold with equality. Note that according to (12), the representative R&D firm allocates the same number of R&D workers to information gathering. As a result, in the remainder of the analysis we focus on a symmetric equilibrium where $s(\omega, t) = \Sigma_i s_i(\omega, t)$ is the industry-wide number of market researchers in industry ω at time t.

Combining (11) and (12), we find that firm i will decide to become a R&D firm if and only if the following arbitrage condition holds:

$$\frac{\ell(\omega, t)}{L(t)} \leq \alpha\mu \tag{13}$$

Eq. (13) can be thought of as a cut-off. After the number of inventors in the total labor force has reached the threshold $\alpha\mu$, the marginal R&D firm will find information gathering more profitable than innovation and the number of market researchers will increase as the size of the workforce not in manufacturing grows. Note that according to (13), each industry ω devotes the same number of R&D workers to innovative tasks, implying that at each instant the economy-wide share of inventors out of total employment, $\int_0^1 \ell(\omega, t)\, d\omega / L(t)$, is constant and equal to $\alpha\mu$, and that any increase in R&D employment results in corporate intelligence.

2.4 The labor market

In each industry ω, consumers only buy from the current quality leader and pay a price equal to λ. Since market demand (5) presents unitary elasticity, at each instant of time t a mass $c(t) L(t) / \lambda$ of workers is employed by current quality leaders. In addition, a mass $L_R(t)$ of researchers (both authors and market researchers) is doing R&D at time t. Since the R&D races are structurally identical in all industries and the measure of all these identical industries equals one, the labor market-clearing condition requires:

$$1 = \frac{L_R(t)}{L(t)} + \frac{c(t)}{\lambda} \tag{14}$$

Observe that when IPR are well protected, information gathering is not as profitable as innovating and (13) is not binding. In this case, there is no incentive for firms to invest in information gathering, with the result that all the employment in R&D is devoted to innovation. On the contrary, when IPR are not well protected, information gathering is profitable for R&D firms and (13) is binding. As a result, if IPR protection is low enough to guarantee that both R&D and information gathering are profitable in the equilibrium, these two research activities coexist in the equilibrium and the share of workers in research, $L_R(t) / L(t)$, will consist of both authors and market researchers. In the next section, we will assume that μ is low and analyze the steady-state solution of the model by focusing on the case in which information gathering is always profitable for firms.

2.5 The stock market

To finance their research projects, firms sell equity shares to consumers. The stock market channels consumer savings towards firms engaged in both R&D and market research and helps households to diversify the risk of holding stocks issued by these firms. Over a time interval of length dt, the shareholder receives a dividend $\pi(t)\,dt$, and the value of the monopolist appreciates by $\dot{v}(t)\,dt$ in each industry. Because each quality leader is targeted by R&D firms[9], each shareholder will suffer a loss of $v(t)$ if further innovation occurs. This event occurs with probability $I(t)\,dt$, whereas no innovation occurs with probability $1-I(t)\,dt$. Efficiency in financial markets requires that the expected rate of return from holding quality leader stock is equal to the risk-less rate of return $r(t)\,dt$ that can be obtained through complete diversification.

A no-arbitrage condition in the capital market thus requires:

$$\frac{\dot{v}(t)}{v(t)}+\frac{\pi(t)}{v(t)}=r(t)+I(t) \tag{15}$$

Eq. (15) states that the profit rate from the stock $\pi(t)/v(t)$ plus the capital gains rate $\dot{v}(t)/v(t)$ equals the market interest rate $r(t)$ plus the instantaneous probability of being driven out of business by another firm $I(t)$.

Plugging (7) into (15) yields:

$$v(t)=\frac{\left(1-\dfrac{1}{\lambda}\right)c(t)\,L(t)}{r(t)+I(t)-\dfrac{\dot{v}(t)}{v(t)}} \tag{16}$$

Finally, by combining the free-entry condition (11) with (16), one obtains the following *no-arbitrage/research equation:*[10]

$$b\kappa=\frac{\left(1-\dfrac{1}{\lambda}\right)c(t)}{r(t)+I(t)-n}\frac{\alpha}{\alpha+\phi+\sigma(t)} \tag{17}$$

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[9] This is so because only innovative R&D can threaten a monopoly position by introducing a radically new idea to produce the $j+1$ quality rung. Since we are dealing with a situation in which the race to the Patent Office occurs instantaneously, once the method for producing the $j+1$ quality level has been discovered, at least one R&D firm (either the original author or a spy) will get the patent and leapfrog the current incumbent's monopoly position instantaneously.

[10] Indeed, by using (11) and accounting for the symmetrical industrial setup, it is easy to verify that $\frac{\dot{v}(t)}{v(t)}=\frac{\dot{\chi}(t)}{\chi(t)}=n$. This result holds because we choose the instantaneous wage rate as *numéraire*.

The no-arbitrage/research equation (17) provides another equilibrium condition for solving the model. The left-hand side is associated with the cost and the right-hand side with the returns of innovating. Observe that in line with Cozzi (2001), the returns of innovating equal the expected flow of profits earned by each leader (7) (appropriately discounted by using the interest rate and the instantaneous probability of being driven out of business by further innovations) times the author's probability of winning the race to the Patent office, $\alpha / \left[\alpha + \sigma\left(t\right)\right]$.

3 The steady state

3.1 Characterization of the steady-state equilibrium

In this Section we focus on the steady-state equilibrium of the model. In doing so, we suppose that condition (13) is binding and define the steady-state equilibrium as follows:

Definition 1 *The steady-state equilibrium for a dynamic economy with endogenous R&D investment and information gathering is the situation in which:* (i) *all endogenous variables grow at constant rates,* (ii) *all markets clear,* (iii) *the long-run rate of innovation is non negative - e.g.* $I\left(t\right) > 0$ *for all* t *-, and* (iv) *the long-run rate of information gathering is non-negative - e.g.,* $\sigma\left(t\right) \geq 0$ *for all* t.

The equilibrium system consists of Eqs. (6), (13), (14) and (17) that have to be solved for the four endogenous variables: the long-run innovation rate I, the long-run rate of information gathering σ, the value of innovation v and the per capita consumption expenditure c.

Let "*" denote steady-state values. Because (13) is binding, the innovation rate of the economy is pinned down in any equilibrium and equals:

$$I^* = \frac{\mu\alpha}{b\kappa}. \tag{18}$$

According to (18), the steady-state innovation rate will be higher, (i) the higher the author's probability of winning the race to the Patent Office, α, (ii) the stronger IPR protection in the economy, μ, (iii) the lower the parameter measuring to what extent population growth affects R&D difficulty, κ, (iv) the lower the technology parameter, b. Thus, in the presence of the PEG specification for the R&D difficulty index, stronger IPR protection has a positive impact on the long-run innovation rate via a permanent increase in the share of innovative R&D employment in the economy.

With the innovation rate pinned down by (18), in order to solve the model we need two equations giving us the steady-state solution for the two remaining endogenous variables c^* and

σ^*. From (6), constant per capita consumption expenditure c^* requires $r(t) = \rho$. Using this result to substitute for the interest rate and (18) to substitute for the innovation rate in (17), the steady-state *no-arbitrage/research equation* is given by

$$b\kappa = \frac{\left(1 - \frac{1}{\lambda}\right) c^*}{\rho + \frac{\mu\alpha}{b\kappa} - n} \frac{\alpha}{\alpha + \phi + \sigma^*} \tag{19}$$

Intuitively, the left-hand side of (19) is related to the cost of introducing a new radical idea while the right-hand side is related to its benefit. The benefit of introducing a new radical idea consists in the present value of the flow of profits earned by each industry leader $(1 - 1/\lambda) c^*$ - appropriately discounted by using the population growth-adjusted interest rate $\rho - n$ plus the instantaneous probability $\mu\alpha/b\kappa$ of being driven out of business by a further innovation - multiplied by the probability that the author can enjoy the fruits of his own innovation $\alpha/(\alpha + \phi + \sigma^*)$.

To close the model, we need a side condition describing the resource constraint of the economy. This condition is the full-employment condition for the labor market (14). As IPR are not perfectly enforced, the share of non-manufacturing workers in the total workforce $L_R(t)/L(t)$ can be split into R&D workers - given by (13)- and market researchers, $\mu\sigma^*$. Consequently, the full-employment condition for the labor market becomes:

$$1 = \frac{c^*}{\lambda} + \mu\alpha + \mu\sigma^* \tag{20}$$

Eq. (20) has a natural economic interpretation. The first term on the right-hand-side is the share of labor in manufacturing, whereas the last two terms are the share of labor in pure innovation and information gathering respectively. Eqs. (19) and (20) complete the description of the steady-state equilibrium of the model. In the next section we carefully discuss under what conditions a steady-state equilibrium such as that described by Definition 1 exists and provide a closed form solution for the two main endogenous variables c^* and σ^*.

3.2 The solution

According to point (*iv*) of Definition 1, a viable steady-state requires a positive rate of information gathering. This point can be represented diagrammatically in (σ, c) space (see Figure 1). Eq. (19) -the R-curve in Figure 1- is globally increasing, whereas Eq. (20) -the L-curve in Figure 1- is globally decreasing in (σ, c) space. The unique intersection between the two curves occurs in the positive orthant if and only if the vertical intercept of (19) is lower than that of (20). It is easy to check that this result occurs if and only if the following restriction on

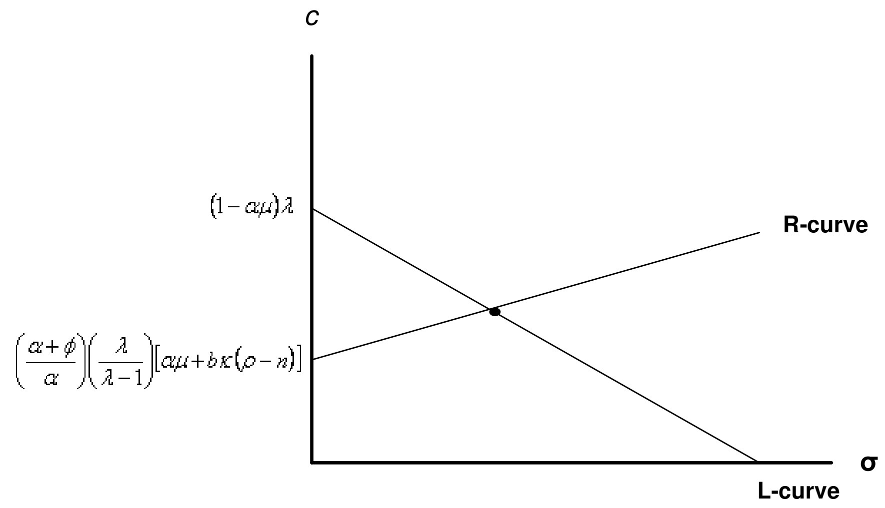

Figure 1: The steady-state equilibrium.

exogenous parameters holds:

$$\mu < \tilde{\mu} \equiv \frac{\alpha(\lambda-1) - b\kappa(\rho-n)(\alpha+\phi)}{\alpha(\phi+\alpha\lambda)} \qquad \wedge \qquad \phi < \tilde{\phi} \equiv \alpha\left[\frac{\lambda-1}{b\kappa(\rho-n)} - 1\right]. \tag{21}$$

where the second inequality is imposed in order to prevent $\tilde{\mu}$ from being negative.

Threshold (21) is strictly related to the R&D arbitrage condition (13). When (21) is obeyed, Eq. (13) is binding and the mass of workers currently hired by the research sector, $L_R(t)$, is larger than cut-off $\mu\alpha L(t)$, with the result that the extra-supply of researchers is engaged in corporate intelligence. This scenario occurs because when the degree of IPR is not very high, the cost of corporate intelligence is affordable for firms, with the result that they will always find it profitable to devote any additional unit of labor to information gathering rather than innovation.

In contrast, when (21) is not obeyed, Eq. (13) is not binding, the mass of workers currently hired by the research sector is lower than cut-off $\mu\alpha L(t)$ and the economy has no room for information gathering. In this scenario the cost of corporate intelligence is not affordable for firms, with the result that it is profitable for them to devote any additional unit of labor to pure innovation rather than corporate intelligence. In this last scenario, the model works like a standard Schumpeterian growth model with endogenous innovation.

Solving (19) and (20) for c^* and σ^* we obtain:

$$c^* = \frac{\lambda(1+\mu\phi)[\alpha\mu + b\kappa(\rho-n)]}{\alpha\lambda\mu + b\kappa(\rho-n)} \tag{22}$$

and

$$\sigma^* = \frac{\alpha \left[\lambda - (1+\mu\phi)\right] - b\kappa\left(\rho - n\right)\phi}{\alpha\lambda\mu + b\kappa\left(\rho - n\right)} - \alpha \tag{23}$$

According to (22), a rise (a fall) in the probability of information leakage ϕ raises (lowers) the steady-state per capita consumption expenditure c^* and lowers (raises) the steady-state rate of information gathering σ^*.[11] Surprisingly, this result tells us that an increase in the outflow of confidential information due to incidental disclosure discourages corporate intelligence. Intuitively, an increase in the flow of leakages enlarges the pool of newly produced ideas that can fall into the hands of rivals. As this new information is freely available to all firms in the economy, the optimal response of firms is to save resources by investing less in corporate intelligence.

Observe that changes in ϕ do not affect the steady-state innovation rate (19). Consequently, a change in the IPR protection regime that makes firms' confidential information more secure does not affect steady-state growth.

All these results can be collected in the following proposition:

Proposition 1 *When restriction (21) holds, a steady-state equilibrium such as that outlined by Definition 1 exists and is unique. In the steady-state equilibrium, strengthening trade secret protection is not an efficient tool to reduce information gathering and spur growth.*

Given the steady-state pair (22)-(23), the aim of the next section is to study the steady-state impact of a stronger IPR regime that makes corporate intelligence more expensive.

4 Strengthening IPR protection

According to Proposition 1, a steady-state equilibrium with corporate intelligence exists if and only if the current strength of IPR protection is lower than threshold (21). Let's now suppose that the government will decide to strengthen IPR protection. Such an intervention can be studied through an increase in parameter μ. Indeed, the level of the μ parameter depends on all those intelligence practices that society considers as acceptable forms of information gathering. The higher μ is, the smaller the set of acceptable practices and the higher the probability that information gathering can be considered as either the illegal or unethical practice of corporate intelligence.

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[11] Indeed, differentiation of (22) and (23) with respect to α gives respectively:

$$\frac{\mathrm{d}c^*}{\mathrm{d}\phi} = \frac{\mu\lambda\left[\alpha\mu + b\kappa\left(\rho - n\right)\right]}{\alpha\lambda\mu + b\kappa\left(\rho - n\right)} > 0 \qquad \wedge \qquad \frac{\mathrm{d}\sigma^*}{\mathrm{d}\phi} = \frac{\alpha\mu\left(\lambda - 1\right)}{\alpha\lambda\mu + b\kappa\left(\rho - n\right)} - 1 < 0,$$

where the sign of the second derivative always holds when $\mu > -b\kappa\left(\rho - n\right)/\alpha$ (i.e. when $\mu > 0$).

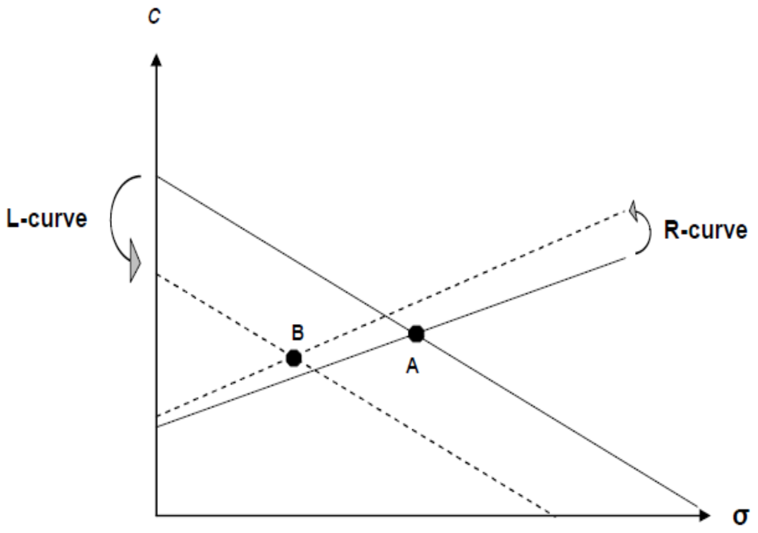

Figure 2: Comparative statics: a fall in μ.

Figure 2 shows how the economy reacts to a permanent increase in μ.[12] Graphically, the L-curve shifts downwards, while the R-curve shifts upwards. The steady-state equilibrium moves from point A to point B, where both the steady-state per capita consumption and the steady-state rate of information gathering decrease.

Proposition 2 *For a given rate of information leakages ϕ, an increase in μ leads to* (*a*) *lower steady-state per capita consumption and* (*b*) *a lower steady-state rate of information gathering.*

The economic intuition behind this result is not difficult to grasp. Let's start by commenting on the steady-state impact on corporate intelligence. An increase in μ has a twofold impact on R&D incentives. Firstly, an increase in μ makes the cost of corporate intelligence increase and the productivity of every corporate intelligence unit fall. This encourages firms to invest more in innovation and less in corporate intelligence, thereby making the steady-state rate of information gathering fall and eventually disappear once μ hits cut-off $\tilde{\mu}$. Secondly, increased μ makes the fruits of innovation more secure and increases the prize for winning the race to the Patent Office. This spurs R&D investment and makes the steady-state rate of innovation (18) increase.

As far as consumption is concerned, a better way of explaining why c^* decreases in the new steady state is to focus on the labor full-employment condition (20). As stated above, a rise in μ makes information gathering decrease. Since the mass of workers who are engaged in

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[12] For the sake of space, the remainder of this section only offers a graphical exposition of the comparative statics results. The analytical details are available in a separate appendix upon request to the author.

information gathering freed by firms is not enough to fulfill the rise in the demand for labor of pure innovative firms, manufacturing must free workers by reducing their sales in order to reach full-employment. Consequently, in the new steady-state equilibrium the economy ends up with more R&D and less manufacturing.

5 Discussion

Thus far we have looked at corporate intelligence from an economic point of view. What has emerged from the previous sections is that corporate intelligence exists only when μ is sufficiently low and that reducing the productivity of corporate intelligence is more effective for economic growth than protecting the trade secret from involuntary leakages. This result has a remarkable impact in terms of policy because it directly impinges on the ways a government can tailor the institutional setting in order to protect confidential information. But is there a way of measuring and determining $\tilde{\mu}$?

As Shing and Spence (2002) point out, there are limits to acceptable forms of information gathering beyond which corporate intelligence might be considered illegal. In order to provide guidelines for distinguishing information gathering from illegal forms of R&D such spying, Crane (2005) has recently proposed a criterion based on ethical concerns that relies on three major points:

1. The *tactics* used to secure information;
2. The *nature of the information* (whether private or confidential);
3. *Public interest.*

As far as the first point is concerned, the *tactics* used in gathering information have to be clearly legal and ethically acceptable. In other words, they can neither take illegal forms, such as breaking and entering a competitor's offices to steal information or infiltrating competitor organizations with professional spies, nor infringe the so-called *deontological code,* i.e. the set of duties of being honest and truthful in business dealings. In this vein, for example, either searching through a competitor's rubbish or contacting a competitor in the fake guise of a potential customer or supplier can be taken as a form of spying.

As regards the *nature of the information*, even though the IPR regime can assign rights to many intangible assets, firms often go to great lengths and invest substantial resources in trying to keep a great deal of information secret from their competitors. With the emergence of information communication technology, the ease of replication of digital information, as well as the refinement of the so-called *reverse engineering* techniques, the unauthorized accessing and exploitation of firms' internal information has increased dramatically over the last decade. The "theft" or "hacking" of sensitive digital information has thus become a major problem for many high tech industries and IPR infringements on digital information have been the subject of numerous recent cases. This is a very difficult problem, whose solution requires policy-making institutions to correctly identify what the substance of IPR is and how IPR-legislation has to be adapted to changes in technology.

Finally, intelligence gathering can turn into spying when it can potentially endanger the *public interest*. Public interest issues can arise in at least two cases. First, when the information acquired generates anti-competitive behavior, including the deliberate removal of competitors or the entrenchment of a monopoly position. Second, public interest issues may arise when corporate intelligence is closely related to national or international security, or when the target firms are involved in designing, producing and servicing military technologies or other security-related products and services. Obviously, it is not so simple to decide whether an act of intelligence gathering is in the public interest or not, especially if it risks having major implications for diplomatic relations.

6 Conclusion

In this paper we have studied the economic implications of corporate intelligence on long-run technological change and economic growth. To accomplish this objective, we have presented a dynamic, scale-invariant Schumpeterian model of growth with trade secret, information leakages and corporate intelligence, and analyzed the steady-state equilibrium effects of introducing stronger protection for firms' confidential information.

In modelling trade secrets, we have split R&D races into two stages. In the first stage, firms invest resources to discover the way to produce a new quality product. In the second, the author of the discovery engages in a race with outsider firms doing corporate intelligence to become the first to introduce a patentable, minor variation to the basic idea. In the passage from the first stage to the second, the author tries to keep the discovery secret but faces a positive probability that some sensitive information about the latest discovery can fall into rivals' hands because of an involuntary information leakage.

We found that the model generates a unique steady-state equilibrium with positive corporate intelligence activity only if the degree of IPR protection in the economy is sufficiently low. We also find that every restriction of the IPR regime aimed at increasing the cost of corporate intelligence is more effective in protecting confidential data than helping authors to better protect their trade secrets. Based on Crane (2005), we have concluded the paper by proposing three possible guidelines to identify the boundaries of corporate intelligence and to distinguish the "legitimate" tactics of information gathering from the "illegitimate" practice of industrial espionage.

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Additional appendix to referees (not to be published)

1. Comparative Statics analysis: An increase in μ

In this appendix we provide the formal proof of Proposition 2. Consider a steady-state equilibrium as that described by the pair (19) and (20). Differentiation with respect to c^* σ^* and μ gives:

$$J \cdot \begin{bmatrix} \frac{\mathrm{d}c^*}{\mathrm{d}\mu} \\ \frac{\mathrm{d}\sigma^*}{\mathrm{d}\mu} \end{bmatrix} = \begin{bmatrix} -\frac{\lambda(\alpha+\sigma+\phi)}{\lambda-1} \\ \lambda\left(\alpha+\sigma\right) \end{bmatrix} \tag{B.2}$$

where the Jacobian is given by:

$$J \equiv \begin{bmatrix} 1 & -\frac{\lambda[\alpha\mu+b\kappa(\rho-n)]}{\alpha(\lambda-1)} \\ 1 & \lambda\mu \end{bmatrix}$$

The determinant of the Jacobian is always positive and reads:

$$|J| = \frac{\lambda\left[\alpha\lambda\mu + b\kappa\left(\rho-n\right)\right]}{\alpha\left(\lambda-1\right)}.$$

Let J_i - with $i = 1, 2$ - denote the matrix formed by replacing the ith column of the Jacobian by the column vector on the right-hand side of (B.2). Using the Creamer rule yields:

$$\frac{\mathrm{d}c^*}{\mathrm{d}\mu} = \frac{|J_1|}{|J|} = \frac{\lambda\left[\alpha\mu\phi - b\kappa\left(\rho-n\right)\left(\alpha+\sigma\right)\right]}{\alpha\lambda\mu + b\kappa\left(\rho-n\right)} < 0$$

$$\frac{\mathrm{d}\sigma^*}{\mathrm{d}\mu} = \frac{|J_2|}{|J|} = -\frac{\alpha\left[\phi + \lambda\left(\alpha+\sigma\right)\right]}{\alpha\lambda\mu + b\kappa\left(\rho-n\right)} < 0$$

where the sign of the first derivative holds when ϕ is not very high.