Technological Revolutions, Entrepreneurship, Intangible Capital and Joint-Ventures

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Very preliminary and incomplete

Abstract

Evidence suggests that we are living a technological revolution. Also, studies document an increase in intangible assets and a wave of exit, mergers and joint-ventures during the last decade. I build an information-theoretic model of entrepreneurship that is consistent with these empirical observations.

A technology appears. Some individuals are better suited than others to develop and to learn about this technology at an early stage. The knowledge they acquire about it is the intangible asset: organizational (or informational) capital. Therefore, as a consequence of the technological revolution we observe a rise in the level of intangible capital.

However, those that are better at learning about a technology are not necessarily those that better manage it. If the intangible capital is transferable we should expect to see a market for it. This is how I explain the wave of exit, mergers and joint-ventures.

1 Introduction

The press described the last decade as one of a technological revolution and baptized it as the 'New Economy' era. Though some of the facts claimed in the non-academic press are still under discussion and close scrutiny by the academic community, many economists argued that the last decade had some distinguishing features:

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1. An increase in the intangible capital (Brynjolfsson and Hyang(2001), Hall (2001)). Except Japan, all the countries presented in the picture that follows have the same type of pattern that led these authors to take this conclusion about the United States: a sharp increase in the market capitalization as a fraction of the GDP, specially in the 90's.

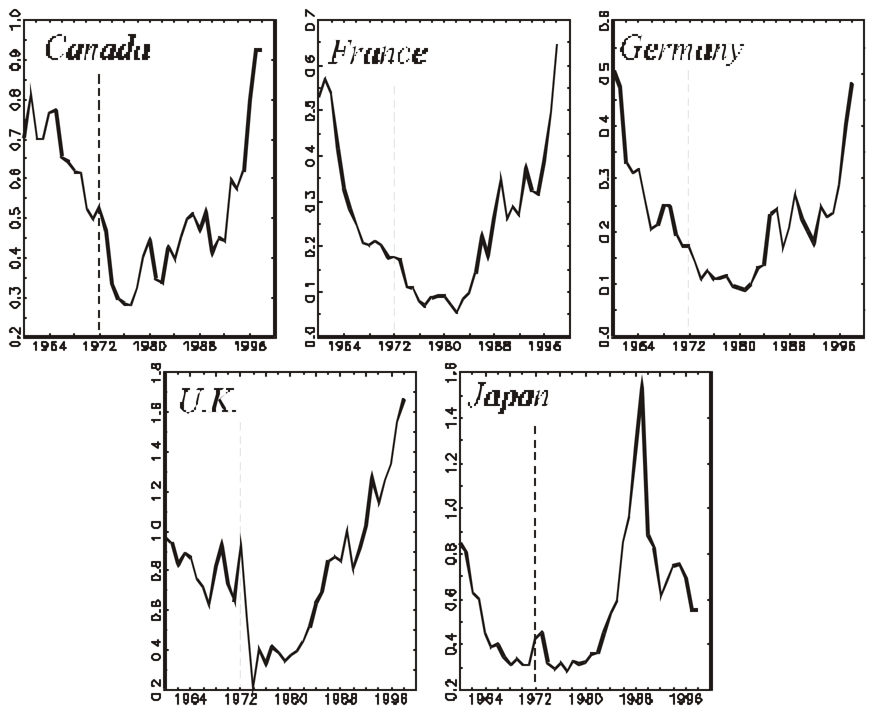

Figure 1: Market capitalization as a fraction of GDP in 5 OECD countries. Source: Hobijn and Jovanovic (2001), figure 2.

2. A merger wave (Jovanovic and Rousseau (2001)) together with a raise in joint-ventures[1]. The picture below is self-explanatory in what concerns the merger wave of the 90's and it also documents a wave in the entry and exit of the firms:

[1] Raise in joint-ventures: data from Thomson Financial quoted in the article "Partner or Perish" in the issue of May 21, 2001 of Forbes.com.

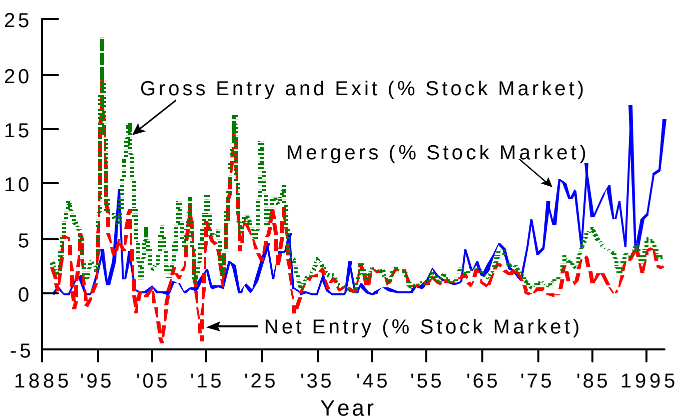

Figure 2: Mergers and net entry capital for exchange-listed firms as shares for stock market capitalization, 1885-1998. Source: Jovanovic and Rousseau (2001), figure 7.

3. A technological revolution based on the Information Technology (Greenwood and Yorukoglu (1997); Hobijn and Jovanovic (2001)).

I propose to take an integrated view of these facts. My conjecture is that a technological revolution led to an increase in intangible capital and that many of the mergers and joint ventures that took place were closely related to the acquisition of this 'new' form of capital. I believe that for some firms the cost of external acquisition of these assets was lower than the cost of internally developing them and this was the main cause for the merger wave in the 90's and the wave of exit of firms in the last decade[2].

I focus on the role of entrepreneurship, following the research line proposed by Schumpeter (1934), remembered by Schultz (1975) and pursued more explicitly by Holmes and Schmitz (1990). Though Holmes and Schmitz recognize the importance of the entrepreneurial ability, they are almost agnostic when it turns to model it. I take a more explicit approach: I describe entrepreneurial ability as the aptitude to learn about a new technology. Hence, my theoretical model is one that is based on the setup proposed

[2] The wave of mergers and exit is documented in the figure 7 of Rousseau and Jovanovic (2001), my figure 2 (see their footnotes 1 and 16 for more details on the construction of the series). The wave of exit is also well documented on figure 7 in Greenwood and Jovanovic (1999), and in figure 11 and table 2 in Hobijn and Jovanovic (2001).

by Jovanovic and Nyarko (1996). This setup is coherent with the evidence presented by Bahk and Gort (1983) that learning by doing is mainly firm specific.

I also take a stand about intangible capital: I interpret it as the organizational or informational capital (as Prescott and Visscher, 1980). The firms that are better at developing and learning about the new technology are not necessarily those that better manage the firms once the technology is developed, so there are gains from trade and room for a market. This is the way I interpret the business transfer and partnerships of the 90's.

What is new in my approach is that: (i) I explicitly model the role of entrepreneurs using an information-theoretic model; (ii) I interpret the knowledge accumulated by the entrepreneurs as intangible capital; (iii) I model mergers (or joint-ventures) as a process of acquisition of this form of capital by relatively more efficient managers.

2 The model

In this economy there is a continuum of individuals characterized by the parameters $\pi = (\lambda, \theta) \in \Pi = \Lambda \times \Theta$. All of the $\pi = (\lambda, \theta)$ individuals have access to a production function that delivers $y(\lambda, k)$ units of output

$$y(\lambda, k) = \lambda k^{\alpha}. \tag{1}$$

That is, the parameter λ is a measure of the managerial ability of the individuals. Each individual owns and manages a firm and receives a compensation

$$w(\pi) = \max_{k} \lambda k^{\alpha} - rk = g(\lambda)h(r), \tag{2}$$

where $g(\lambda) = \lambda^{\frac{1}{1-\alpha}}$ and $h(r) = (1-\alpha)(\frac{\alpha}{r})^{\frac{\alpha}{1-a}}$. In this state of the economy, the entrepreneurial ability plays no role

At date T, the production function becomes

$$y_t(\lambda, k) = \gamma[1 - (s_t - z_t)^2]\lambda k^{\alpha} = q_t y(\lambda, k), \tag{3}$$

where $q_t = \gamma[1 - (s_t - z_t)^2]$[3]. As I will explain later, this parameter q_t is related with the concept organizational capital. This parameter q_t depends on the realization of a random variable s_t and on the decision the manager

[3] My specification follows closely that of Jovanovic and Nyarko (1995, 1996).

takes before observing the realization of the random variable, z_t. The random variable is a noisy observation of a parameter μ, $s_t = \mu + \sqrt{\theta}\sigma\omega_t$, where μ and σ are constants, $\sigma > 0$, and ω_t is a standard Wiener process. Agents know γ and the distribution of ω_t but they don't know μ, though they have prior beliefs about it. The precision with which they can infer the value of μ from the observation of s_t differs across individuals: the reciprocal of parameter θ defines their entrepreneurial ability. I assume the prior is common across individuals and is a normal distribution with mean m and variance s.

The individuals are risk neutral and the choice of level of capital must be done before the resolution of uncertainty (r is known and constant over time). There are no adjustments costs of capital and no cost of adjusting z, so the manager's problem remains a one period problem:

$$\max_{z_t,k_t} y(\lambda, k_t)E_t^{\theta}(q_t) - rk_t, \tag{4}$$

where $E_t^{\theta}(.)$ denotes the conditional expectation at t formed by entrepreneur θ. It is clear that the decision z_t does not depend on the level of capital, so to solve the above equation is the same as to solve a problem in two stages: first, maximize $E_t^{\theta}(q_t)$, and then determine the optimal level of k_t, i.e.,

$$\max_{k_t} \left\{ \max_{z_t} E_t^{\theta}[1-(s_t-z_t)^2] \right\} \gamma\lambda k_t^{\alpha} - rk_t. \tag{5}$$

The optimal decision z_t is

$$z_t = E_t^{\theta}(s_t) = E_t^{\theta}(\mu), \tag{6}$$

so

$$\max E_t^{\theta}(q_t) = \gamma E_t^{\theta}[1-(s_t-E_t^{\theta}(\mu))^2] = \gamma\left[1 - E_t^{\theta}[\mu - E_t^{\theta}(\mu)]^2 - \theta\sigma^2\right]. \tag{7}$$

From Bayesian inference we know that the posterior variance over μ, given the observation of t signals, of an individual θ is

$$Var_t^{\theta}(\mu) = E_t^{\theta}[\mu - E_t^{\theta}(\mu)]^2 = \frac{\theta\sigma^2 s}{\theta\sigma^2 + st}. \tag{8}$$

The (expected) compensation of the entrepreneur θ is

$$w_t(\pi) = \max_{k_t} \gamma\left[1 - \frac{\theta\sigma^2 s}{\theta\sigma^2 + st} - \theta\sigma^2\right]\lambda k_t^{\alpha} - rk_t = g_t(\theta,\lambda)h(r), \tag{9}$$

where $g_t(\theta,\lambda) = \left[\gamma\lambda\left(1-\frac{\theta\sigma^2 s}{\theta\sigma^2+st}-\theta\sigma^2\right)\right]^{\frac{1}{1-\alpha}} = g(\lambda)i(t,\theta)$ where $i(t,\theta) = \left[E_t^\theta(q_t)\right]^{\frac{1}{1-\alpha}} = \left[\gamma\left(1-\frac{\theta\sigma^2 s}{\theta\sigma^2+st}-\theta\sigma^2\right)\right]^{\frac{1}{1-\alpha}}$ is an increasing function of the level of intangible (informational or organizational) capital, $E_t^\theta(q_t)$. The rule of accumulation of this form of capital is highly non-linear.

The way I model this learning process is not new and it is borrowed from Jovanovic and Nyarko (1996). It is interesting to point that in this learning process there are no spillover effects and that the learning is firm specific and not captured by the inputs. This type of learning is only transferable through the transfer of ownership of the firm. Bahk and Gort (1983) present strong evidence in favor of this modelling procedure.

Definition 1 *There is a technological revolution if* $\gamma\left(1-\theta\sigma^2\right) > 1, \forall\theta\in\Theta$.

This definition says that once all the learning about the new technology has finished, every manager will be producing and earning more than before.

2.1 The organizational capital is non-transferable

I start assuming that the firms are not able to transfer their organizational capital; the information each individual gathers about the new technology is not transferable to other individuals. We can think of this as a case in which frictions associated with the transaction totally destroy the knowledge acquired[4]. In this environment there is no role for a market of organizational capital, it is as if the individuals were living in autarchy.

The problem each individual π faces by time T is

$$\max_{t_a} \int_0^{t_a} e^{-rt} w(\pi)dt + e^{-rt_a}\int_0^\infty e^{-rt} w_t(\pi)dt, \tag{10}$$

where t_a, the decision variable, is the time to the adoption of the new technology (it is the same as the date at which it occurs if I normalize T to zero).

The FOC of this problem is

$$e^{-rt_a}\left[w(\pi) - r\int_0^\infty e^{-rt} w_t(\pi)dt\right], \tag{11}$$

[4] In the article "After the deal" published in the January 7, 2001 issue of *The Economist* it is argued that there is a "soft trap" in the mergers that can destroy value. I interpret this section as an extreme interpretation of the view presented in that article.

and its sign depends on the sign of $w(\pi) - r\int_0^\infty e^{-rt} w_t(\pi)dt$. That is, if

$$\int_0^{t_a} e^{-rt} w(\pi)dt > e^{-rt_a} \int_0^\infty e^{-rt} w_t(\pi)dt \Leftrightarrow w(\pi) - r\int_0^\infty e^{-rt} w_t(\pi)dt > 0 \tag{12}$$

$FOC > 0$, so $t_a = \infty$, i.e., it is better to never adopt the new technology; if

$$\int_0^{t_a} e^{-rt} w(\pi)dt < e^{-rt_a} \int_0^\infty e^{-rt} w_t(\pi)dt \Leftrightarrow w(\pi) - r\int_0^\infty e^{-rt} w_t(\pi)dt < 0 \tag{13}$$

$FOC < 0$ and so $t_a = 0$, it is better to adopt the new technology immediately. The case in which $FOC = 0$ is uninteresting because of the indeterminacy (and indifference) result, so I will overlook it.

The problem of the individual π, *adopt it now or never adopt it*, is better described by the problem

$$\max \left\{ \int_0^\infty e^{-rt} w_t(\pi)dt, \quad \int_0^\infty e^{-rt} w(\pi)dt \right\}, \tag{14}$$

or equivalently

$$\max \left\{ \int_0^\infty e^{-rt} g_t(\pi)dt, \ \frac{g(\pi)}{r} \right\}, \tag{15}$$

or

$$\max \left\{ \int_0^\infty e^{-rt} i(t,\theta)dt, \ \frac{1}{r} \right\}. \tag{16}$$

It is easy to check that $\frac{\partial}{\partial\theta}\int_0^\infty e^{-rt} i(t,\theta)dt < 0$.

Proposition 2 *If $\int_0^\infty e^{-rt} i(t,\theta_L)dt < \frac{1}{r}$ no one adopts the new technology; if $\int_0^\infty e^{-rt} i(t,\theta_H)dt > \frac{1}{r}$ everyone adopts the new technology; if $\int_0^\infty e^{-rt} i(t,\theta_L)dt > \frac{1}{r} > \int_0^\infty e^{-rt} i(t,\theta_H)dt$ then $\exists\theta^* \in \Theta$ such that $\int_0^\infty e^{-rt} i(t,\theta^*)dt = \frac{1}{r}$, i.e., $[\theta_L, \theta^*]$ will adopt the technology, while $[\theta^*, \theta_H]$ will keep using the old technology.*

Proof. *Straightforward using graphic analysis.* ■

What is surprising in this proposition is that the only factor that matters for the adoption of the new technology is the entrepreneurial ability θ and not the managerial skills λ. In the case that only part of the total population adopts the technology, there will be both good and bad managers adopting the new technology, as long as they are good entrepreneurs; the bad entrepreneurs, independently of their managerial skills, will never adopt the new technology.

Proposition 3 *Given that the new technology is adopted, (i) the higher is the managerial skill the higher will be the gains from the adoption. Moreover, (ii) the net gains from the adoption of technology increase more than proportionally with the managerial skill.*

Proof. *(i)* $\frac{\partial}{\partial\lambda}\left\{g(\lambda)\left[\int_0^\infty e^{-rt}i(t,\theta)dt \ -\frac{1}{r}\right]\right\} > 0$; *(ii)*$\frac{\partial^2}{\partial\lambda^2}\left\{g(\lambda)\left[\int_0^\infty e^{-rt}i(t,\theta)dt \ -\frac{1}{r}\right]\right\} > 0$. ■

Definition 4 *A technological revolution is a manna for manager* θ *if* $\gamma\left(1-s-\theta\sigma^2\right) > 1$ *and it is costly for manager* θ *if* $\gamma\left(1-s-\theta\sigma^2\right) < 1$.

Definition 5 *There is leapfrogging if for* $\pi' = (\lambda', \theta')$ *and* $\pi'' = (\lambda'', \theta'')$ *such that* $\lambda' < \lambda''$, *and* $\theta' \in [\theta_L, \theta^*]$ *and* $\theta'' \in [\theta^*, \theta_H]$, $\lambda'\gamma(1-\theta'\sigma^2) > \lambda''$.

2.1.1 The organizational capital is tradable

Assume there is a technological revolution that is costly for all individuals. Now I introduce the assumption that the informational capital about a new technology can be traded. I assume that the knowledge accumulated by an agent $\pi = (\lambda, \theta)$ can be transferred to other agent $\pi' = (\lambda', \theta')$ at some price. Furthermore, I assume that the transfer is not only of the informational capital accumulated up to then but also of the ability to learn in the future[5].

Given that there are no external effects, if the adoption of the new technology is socially optimal we must expect to see competitive markets allocating the resources in the most efficient way for the adoption of the technology to take place. In autarchy, low θ individuals will adopt the technology. However, once the learning is done, if a market exists, we might expect the relatively most efficient entrepreneurs to sell the knowledge of technology to the relatively most efficient managers (if the good entrepreneur is not himself a good manager).

At the time there is a technological revolution, the individuals decide whether to be an entrepreneur or a manager or both. An entrepreneur is an

[5] We can think of this as thecase in which the organizational capital of a company is fully absorbed by some other company. The best interpretation is the one of partnerships but we can also extend it to mergers if we believe that the organizational structure and the ability to learn are maintained after the take over.

individual that develops a technology, learns about it and after he acquires some level of knowledge about it he sells it and his services to a manager. A manager is an individual that only works with "mature" technologies; he does not develop technologies, but applies them to a firm by buying the knowledge the entrepreneurs accumulated about it. I assume that all the individuals in each class behave competitively, taking the sequence of the price schedule $\{p_\tau(i)\}_{\tau=0}^{\infty}$ as given, where i is the level of informational capital and it is a function of both τ and θ.

The value of being an entrepreneur includes the decision of when (if ever) to sell the informational capital:

$$V_E(\lambda, \theta) = \max_{\tau^s} \int_0^{\tau^s} e^{-rt} \lambda^{\frac{1}{1-\alpha}} i(t, \theta) dt + p_{\tau^s}\left(i(\tau^s, \theta)\right). \tag{17}$$

The value of his activity is the sum of the discounted earnings plus the discounted value of the informational capital when he sells it. I assume that when the individual sells his informational capital he cannot use it and his entrepreneurial ability is sold to the best managers (this is the sense in which this is also a matching problem-why doesn't he integrate immediately? because there are still gains that good managers can do, while the best entrepreneurs are learning; however, by date T everyone already knows with whom to match some periods ahead).

The value of being a manager includes the decision of when (if ever) to adopt the new technology:

$$V_M(\lambda, \theta) = \max_{\tau^d, \theta^d} \int_0^{\tau^d} e^{-rt} \lambda^{\frac{1}{1-\alpha}} dt + e^{-r\tau^d} \int_0^{\infty} e^{-rt} \lambda^{\frac{1}{1-\alpha}} i(t + \tau^d, \theta^d) dt - p_{\tau^d}\left(i(\tau^d, \theta^d)\right). \tag{18}$$

Therefore, the problem for any individual $\pi = (\lambda, \theta)$ is

$$V(\lambda, \theta) = \max\left\{V_E(\lambda, \theta), V_M(\lambda, \theta)\right\}. \tag{19}$$

The case of the entrepreneur/manager is also included in this formulation. An individual π is an entrepreneur/manager when $\tau^{s*}(\pi) = \infty$ and $V(\pi) = V_E(\pi)$.

Definition 6 *An* ***equilibrium*** *is a sequence of price functions $\{p_\tau(q)\}$ and a set of quantities $\tau^{s*}(\lambda, \theta)$, $\tau^{d*}(\lambda, \theta)$, $\theta^{d*}(\lambda, \theta)$ such that (i) prices clear the market at every τ and θ, i.e., $Q^s(\tau)d\tau = Q^d(\tau)d\tau$ and $Q^s(\theta)d\theta = Q^d(\theta)d\theta$, where $Q^s(x)dx = \int_{(\lambda,\theta):(\lambda,\theta)\in E \wedge x(\lambda,\theta)=x} x dF(\lambda, \theta)$ and $Q^d(x)dx =$*

$\int_{(\lambda,\theta):(\lambda,\theta)\in M\wedge x(\lambda,\theta)=x} xdF(\lambda,\theta)$; *and (ii)* $\tau^{s*}(\lambda,\theta) = \arg\max_{\tau^s} \int_0^{\tau^s} e^{-rt}\lambda^{\frac{1}{1-\alpha}} i(t,\theta)dt + p_{\tau^s}\left(i(\tau^s,\theta)\right)$, $[\tau^{d*}(\lambda,\theta), \theta^{d*}(\lambda,\theta)] = \arg\max_{\tau^d,\theta^d} \int_0^{\tau^d} e^{-rt}\lambda^{\frac{1}{1-\alpha}} dt + e^{-r\tau^d} \int_0^{\infty} e^{-rt}\lambda^{\frac{1}{1-\alpha}} i(t+\tau^d,\theta^d)dt - p_{\tau^d}\left(i(\tau^d,\theta^d)\right)$.

2.1.2 Characterizing the equilibrium

It is easy to see that $V_M(\lambda,\theta)$ does not depend on θ, that is, only the managerial ability matters. This happens because I am imposing the assumption that the precision in extracting the signal will be the one of the firm that is acquired, not of the manager itself or a combination of both[6]. So I can write $V_M(\lambda,\theta) = V_M(\lambda)$. The level of managerial ability that makes an individual with an entrepreneurial ability equal to (the reciprocal of) θ indifferent between being a manager or an entrepreneur is thus the solution to the equation

$$V_M(\bar{\lambda}) = V_E(\bar{\lambda},\theta). \tag{20}$$

So, for each value of θ we can determine the threshold level of managerial ability:$\bar{\lambda}(\theta)$. Individuals with the same θ but with higher λ than $\bar{\lambda}(\theta)$ will be managers; the others will be entrepreneurs.

Conjecture 7 *The function $\bar{\lambda}(\theta)$ is decreasing in θ, that is, the better entrepreneur an individual is (the lower is θ), the higher must be his managerial skill to make him indifferent between being a manager or an entrepreneur (see figure 3 in appendix).*

3 Conclusion

Much work still remains to be done in this paper. Here I presented the setup I think is adequate to study issues related to the 'New Economy' era: technological revolution, rise in the intangible capital and a mergers (exit) wave. A complete characterization of the equilibrium will describe the price schedule and the "identity" of the managers and entrepreneurs.

[6] It is easy to show that this assumption has microeconomic foundations. By now I will not elaborate on this.

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Appendix

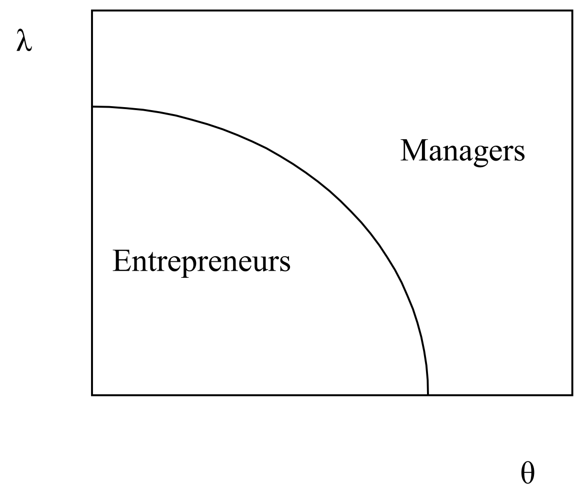

Figure 3