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The financing of innovation: an evolutionary approach to firm behavior

O financiamento da inovação: uma abordagem evolucionária do comportamento da firma

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Resumo: Este artigo discute a dinâmica do financiamento à inovação pela perspectiva teórica evolucionária. A decisão da firma sobre seu comportamento quanto a inovação foi analisada pela aplicação da ótica dos regimes tecnológicos e pela ênfase na relação existente entre finanças e inovação. Para se entender a disponibilidade de financiamento para o processo inovativo foi incorporada à teoria evolucionária a relação entre os estágios de crescimento da firma e a alocação de fontes de capital. O artigo demonstra que para cada padrão tecnológico e estágio de desenvolvimento, a firma apresenta um tipo diferente de comportamento na busca pelo financiamento da inovação.

Palavras-chave: Financiamento; Teoria Evolucionária; Comportamento da Firma.
Classificação JEL: O39, L20, D21

Abstract: This article discusses the financing of innovation based on the evolutionary theory. The goal is to bring together elements that elucidate a firm's behavior towards the innovation process. These elements include technological regimes and the relationship between finance and innovation. The discussion goes further into the evolutionary theory by incorporating the stages of growth of an innovative firm and the preference of innovation funding sources. The conclusion is that for each technological pattern and at each stage of development, a firm tends to present a different type of behavior in seeking financing for innovation.

Keywords: Financing innovation; Evolutionary theory, Firm behavior.
JEL Classification: O39, L20, D21

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> Indeed, the term 'neo-Shumpeterian' would be as appropriate a designation for our entire approach as 'evolutionary'. More precisely, it could reasonably be said that we are evolutionary theorists *for the sake* of being neo-schumpeterians (NELSON; WINTER, 1982, p.39).

1. Introduction

In *The theory of economic development* (TED), Schumpeter [1911] initiated the discussion about the close relationship between finance and innovation. In Schumpeter's conception, not every innovative firm can mobilize by itself all the capital necessary to finance research projects, the expansion of production, the development of prototypes, and the launching of new products. The offer of credit appears as a precondition for economic development. On the other hand, it is observed that the credit system also needs the transformations arising from the industrial-innovative dynamics to guarantee higher remuneration for the monetary capital. Therefore, finance and innovation seem to articulate within a self-reinforcing system in which capital is needed to innovate while innovating to remunerate capital.

The following approaches stand out among the attempts to discuss the role finance plays in economic development or on the financial system in its broadest sense: i) financial economics on the orthodox view of the relationship between financial system development and economic growth (Levine, 1997; King and Levine, 1993; Levine and Zervos 1998; Cojocaru *et al*, 2016; Pan and Mishra, 2018); ii) institutional economics on the relationship between financial structures and economic development (Gerschenkron, 1962; Zysman, 1983); and iii) evolutionary economics on the relationship between innovative activity and allocation of financial resources (Freeman and Perez, 1988; Dosi, 1990; Perez, 2002; Mazzucato, 2013; Grilli *et al*, 2018).

Financial economics literature supports the thesis that the development of the financial system is critical to economic growth, but it faces at least two limitations: i) it pays little attention to the structural changes needed to accommodate the mutations of the financial system, and ii) it justifies the emergence of different types of financial arrangements as a response to market imperfections. The institutional economics approach provides clues to understanding how financial institutions and the organizational structures of firms are the result of an evolutionary and co-constitutive process[1]. However, it does not explore in depth the institutional transformations that the financial and innovation systems undergo to meet the demands of industrial-innovative dynamics. Evolutionary economics arguments point to a co-evolution between finance and innovation but the available literature has very little information on the role of credit in the innovation process.

Although evolutionary economists have not delved deeply into the theme related to the role of finance in innovation, this approach seems to be, among the three perspectives

[1] As seen in Veblen (1961), the ontological assumption of co-constitution assumes that actors are shaped by their social environment at the same time that they shape the social structure in which they live.

presented, a good starting point to understand the transformations that take place in the industrial-innovative dynamics.

In a recent overview of the development of evolutionary literature Nelson *et al* (2018) describe the paths taken in recent years and explore the potential of this perspective. However, it is demonstrated that this close relationship between finance and innovation remains under-explored in evolutionary literature. Therefore, this paper aims to highlight the dynamics of innovation financing from the perspective of evolutionary economics. To achieve our proposed goal, the allocation of financial resources is addressed based on the behavior of the firm, the characteristics that define the sector-based differences of innovation systems and the stages of growth/development of innovative firms. These characteristics may affect the way a firm will engage in different types of innovation and the sources available to it.

To meet the proposed objective, this paper is divided into six sections, including this introduction. In the second section we will discuss Nelson and Winter's legacy based on a discussion of a firm's behavior. In the third section we will discuss Schumpeter's emphasis on the role of the allocation of financial resources in the innovation process and explore the Schumpeterian dichotomy between the role played by firms in the innovation process. In the fourth section we will deal with the contributions made by evolutionary economics to the study of innovation systems by discussing how industry patterns of innovation activity affect the type of investments required to develop new products and/or services. With this in mind, we also investigate how sectorial patterns affect the distribution of innovation activity among firms. In the fifth section we will address the challenges that the innovation process poses to the financing of the industrial-innovative dynamics. From these challenges, the discussion moves on to understanding the stages of firm development and the need for financial resources at each stage. The sixth section presents our final remarks.

2. Firm Behavior

The so-called ‘theory of the firm’ was constructed to support the theoretical investigation of central problems in economics from a mainstream perspective – what, how many and how to produce. Price determination and the allocation of resources are therefore at the heart of the neoclassical approach to firm behavior.

Neoclassical theory understands a firm as a metaphysical unit making decisions about the quantity to be produced and the form of production function. According to this theory, the entrepreneur is a rational economic agent who decides how much to produce and how to produce, given the market constraints - consumers and competitors - and the technological constraints. Given the possible combinations among inputs and technically feasible products, a firm will maximize its profit by producing within the most advanced stage of technical knowledge. Entrepreneurs will produce after evaluating information available so that the result is the maximization of their goal - optimal choice. In general,

the behavior of the firm in the neoclassical approach is supported by two central pillars identified by Nelson and Winter in *An Evolutionary Theory of Economic Change* (1982): maximizing behavior and the concept of equilibrium.

Maximizing behavior comprises three components. The first one involves specifying what it is that a firm aims to maximize. Overall, firms seek to maximize profit or present value. The second step is to specify its 'product set', which is a set of activities or techniques that the firm knows how to do. Finally, there is a presumption that the firm's attitude results from choosing the maximizing option – an action that maximizes the degree to which its objective is achieved (NELSON; WINTER, 1982, p. 12).

Therefore, the analysis of firm behavior under the maximizing hypothesis arises from an appraisement of their goals and choices. It carries the assumption "that [it] is a global, faultless, once-and-for-all optimization over a given choice set comprising all objectively available alternatives" (NELSON; WINTER, 1982, p.31). In short, the maximization hypothesis imposes "behavioral rules" or "decision rules" on firms, which will determine what firms do under external – market – or internal conditions (NELSON; WINTER, 1982, p. 12).

The concept of equilibrium defines the logic of the neoclassical model. Models vary in detail, complexity, and sophistication but, in general, equilibrium analysis follows a basic outline (NELSON; WINTER, 1982, p. 13). The supply and demand curves of a market are the aggregation of the individual supply and demand curves. For each economic agent, each curve describes the quantity traded that would be most desirable at each possible value of the market price. The value of the price is determined by the conditions of equilibrium between supply and demand, which selects the price that exactly matches the aggregate quantity desired by buyers with the aggregate quantity that sellers wish to sell.

> The role and result of all these equilibrium conditions is to generate within the logic of the model conclusions about economic behavior itself – as distinguished from the conclusions about the rules of behavior that are generated by the maximization analysis (NELSON; WINTER, 1982, p.13).

Neoclassical models use a variety of mathematical instruments that are growing more complex and refined every day. Therefore, these models still focus on maximization and equilibrium instead of going further into the root of the problem. Just like Nelson and Winter (1982), Edith Penrose (2006 [1959], p.48-49) points out that the problem with the theory of the firm is not the degree of abstraction but the kind of abstraction it carries. The theory of the firm does not distinguish between, among others, the nature, the size, or the financial situation of different firms. As a result, all firms are equal and exhibit the same behavior. By introducing uncertainty and bounded rationality, the evolutionary approach

inherited from Nelson and Winter (1982) presents another pattern of the firm's behavior, treating it as a living organism.

The evolutionary model of firm behavior refuses the maximizing hypothesis, the neoclassical's general objective and its defined set of possible choices, and the rationalization of the firm's optimal choice (NELSON; WINTER, 1982, p. 14). In the evolutionary view, routines define the firm's behavior. This approach treats routines and genes in similar terms. Just like genes, routines are hereditary and selectable. For example, as a biological organism that comes from an evolutionary process, new organizations arise from the learning of old ones. Moreover, organisms with certain routines may perform better than others. For an organization, better performance may increase its competitive advantage over time and induce imitative behavior (NELSON; WINTER, 1982, p.15).

Although the evolutionary approach recognizes the existence of stochastic elements in both decision determinants and outcomes, it believes that routines guide firm behavior. Routines comprise three classes: operational routines, period-by-period routines, and long-term routines. Operational routines guide firms' behavior in the short run. In other words, they set what firms do considering their previous stock of factories, equipment, and other production factors that cannot increase rapidly. The second set of routines determines the period-by-period magnitude of a firm's capital stocks, investments in research and development (R&D), and others input/output affecting variables. And finally, firms have routines that work to modify various aspects of their operating characteristics over time. They include long-term routines to analyze performance, revision needs, or even radical change requirements (NELSON; WINTER, 1982, p.16-18). In short, routines - which evaluate choices, opportunities, and the need for change – are the guides to decision processes. Mistakes and successes may occur, and learning is the ultimate result.

The evolutionary firm is profit-seeking. Even though profit is its goal, it does not exhibit a profit-maximizing behavior. The uncertainty and bounded rationality of agents will define a firm's environment. This background makes optimizing behavior impossible. As emphasized by Shiozawa (2019), there is no optimal economic entity – behavior, technology, institution, organization, etc. – because all of them have bounded rationality evolution. Yet,

> [c]ompetitive stimuli and pressures are (…) an important part of the environment for the decision making that goes on in each of the firms in an industry. Competition forces not only shape voluntary business decisions – they help to set involuntary, survival-related constraints on business decisions (NELSON; WINTER, 1982, p.32).

Thus, the evolutionary approach emphasizes the dynamism of the market process in which competitive forces generate impulses for change. Technological innovation is the main source of change. Competitive rivalry creates imbalances that set off Schumpeter's

'creative destruction' process. In contrast to the neoclassical's equilibrium highlight, the concept of disequilibrium (change) is central to the evolutionary approach.

Nelson and Winter (1982) consider the learning process and knowledge as crucial elements in promoting innovation under an uncertain and bounded rationality environment. The fight for survival induces the quest for innovation to increase profit. However, due to their different routines, firms will have different strategies to pursue their goals. Notwithstanding, their organization also limits their strategies. Nelson and Winter (1982, p. 38) argue that "there are strong connections both between firm's strategy and its appropriate organizational structure and between the techniques commanded by a firm and its organization." For example, innovation investment decisions in R&D are affected by a firm's size and financing capacity.

Regarding firm's innovation behavior decision analysis, one must consider the *technological regimes* advocated by Nelson and Winter (1982), which this article presents later on. But even though it explains the performance of both large firms and new and small ones in the innovation process, the examination is not complete. A consistent analysis must also include the relationship between finance and innovation. Next, we will highlight the relevance of the financial dimension to the innovation process, which was pioneered in Schumpeter's work.

3. Schumpeter and the financing of innovation

In a schumpeterian approach, the articulation between finance and innovation is multifaceted and organized in at least two systems that operate in parallel in the economy. The first includes the new and small so-called innovative firms. They depend to a large extent on the supply of credit by external agents. The second one is related to large firms. These, in turn, generally use profits retained from previous productions to develop new products and services. Following these two systems, the economic literature divides Schumpeter's work into *Mark I* and *Mark II*.

In *Schumpeter Mark I* – which encompasses TED and *Business cycles: a theoretical, historical, and statistical analysis of the capitalist process* (BC) – the author highlights the importance of credit creation and the role of entrepreneurs in the emergence of new industries. In contrast, *Schumpeter Mark II* – represented by *Capitalism, socialism and democracy* (CSD), published in 1942 – emphasizes the role played by internal finance and R&D activities in large firms to promote development. This change in Schumpeter's view reflects both the transformations in capitalism itself and the relevance of large, established firms to innovation.

It is important to note that *Schumpeter's Mark II* does not invalidate *Schumpeter's Mark I* or that *Schumpeter Mark I and II* operate statically. In his time, Schumpeter could

not manage to verify whether new and small firms and large firms could work in parallel in the economy and be relevant for different types of innovation. Nowadays, one may know that there are sectors where the volume of resources required to develop new products restricts technological leadership to large firms. However, there are other industries in which new and small firms are protagonists of technological progress.

In TED, Schumpeter's initial assumption starts from a steady state of the economy, or a "circular flow" of equilibrium, in which there would be no development, capital accumulation, or profit. To break through this situation, Schumpeter emphasizes the essential role of the entrepreneur and innovation. The entrepreneur is responsible for promoting revolutionary changes by exploring new combinations, such as i) the development of new goods; ii) the introduction of new production methods or new ways to commercially handle a commodity; iii) the opening of new markets; iv) the discovery of new raw materials; and, v) the development of new organizational forms (SCHUMPETER, 2012 [1911], p. 66). As these new combinations emerge, they are incorporated by new firms and alter forever the previously existing state of equilibrium. Thus, the 'creative destruction' triggered by innovation comes into play.

However, undertaking new combinations involves more than just the “acts of will” – or the psychosocial motivations – of an individual. According to Schumpeter, purchasing power is also an essential part of the innovation process (SCHUMPETER, 2012 [1911], p. 68). Since the entrepreneur is neither the owner of the means of production nor has retained profits to finance himself (as large, established firms do), the demand for credit created *ad hoc* is a necessity (SCHUMPETER, 2012 [1911], p. 106). The entrepreneur becomes an entrepreneur only after obtaining credit: “[w]hat he [entrepreneur] first wants is credit. Before he requires any goods whatever, he requires purchasing power. He is the typical debtor in capitalist society”. (SCHUMPETER, 2012 [1911], p. 102). A capitalist is the one who provides this purchasing power to an entrepreneur.

Although a capitalist can be any individual, including an entrepreneur or institution, Schumpeter emphasized the role of commercial banks in his analysis. In Schumpeterian theory, the banker is the promoter. That is, he is the intermediary between the entrepreneur and the owners of the means of production. By creating credit, a commercial bank expands the means of payment available to entrepreneurs, thus becoming a key element in economic development. According to Schumpeter, credit creation is “the monetary complement of innovation” (1939, p.109). By attributing this leading role to the financial system, Schumpeter suggests that money matters.

In BC, the separation of roles between the entrepreneur and the capitalist becomes clear. In this work, Schumpeter (1939) states that it is not easy to tell who the entrepreneur is. He can be the manager or salaried employee, or principal shareholder. The characteristics that distinguish entrepreneurs from other individuals are their leadership ability and initiative in adopting new combinations, not the possession of capital. Therefore, providing credit is not the function of the entrepreneur. Thus, Schumpeter states

that it is the capitalist who assumes the risks inherent to entrepreneurial activity. Entrepreneurs, in turn, put their reputation and their jobs at risk.

The granting of credit depends on the evaluation of the risks associated with the new combinations: “the banker should know and be able to judge what his credit is used for” (SCHUMPETER, 1939, p. 115). As a result of his reflection, Schumpeter points out that the great challenge of innovation financing is precisely the difficulty banks have in analyzing the risks of an activity that is still unknown and surrounded by uncertainties.

> […] the failure of the banking community to function in the way required by the structure of the capitalist machine accounts for most of the events which the majority of observers would call “catastrophes”. Since such failure primarily shows in dealing with novel propositions – where judgment is most difficult and temptation strongest – an association has developed between financing innovation and miscarriage or misconduct which, however understandable, does not make analysis any easier (SCHUMPETER, 1939, p. 117).

Since it is not possible to determine the success of innovation *a priori*, the entrepreneur must be able to convince the capitalist that the profits expected from the adoption of new combinations will be high enough to cover the costs of production, pay interest, and reimburse the capitalist. Schumpeter also clarifies that profit is not a mere incentive for economic development when he considers that the generation of profit stimulates new investments by making the emergence of new sources of profit possible. Besides the motivation for capital accumulation, profit is a necessary condition for accumulation itself. That is the idea of ‘creative accumulation’ developed in *Schumpeter Mark II.*

Meanwhile, in CDS, new arguments about the relationship between finance and innovation are presented. While in TED and BC, Schumpeter had focused on the role played by the entrepreneur and external financing; in CDS, he downplays the need for credit creation and states that innovation was due to the routine of large established firms. Due to retained profits, large firms have sufficient resources for self-financing. For Schumpeter, this type of firm had become "the most powerful engine" of economic development (1942, p. 106).

Schumpeter's argument regarding the superiority of large firms in the innovation process is based on the thesis that “there are superior methods available to the monopolist which either are not available at all to a crowd of competitors or not available to them so readily” (SCHUMPETER, 1942, p. 101). "The perfectly bureaucratized giant industrial unit […] ousts the small and medium-sized firm" (SCHUMPETER, 1942, p. 134). For Schumpeter, large firms can attract ‘brilliant’ minds, employ more financial resources (SCHUMPETER, 1942, p. 110) to introduce new combinations, and develop mechanisms to protect themselves against the high risks of investments in innovative projects.

To sum it up, *Schumpeter Mark I and II* elucidate that one's capital must be available to assume the risks inherent in financing new combinations, whether undertaken in the "garage of a house" or the laboratory of a large firm. They also emphasize the close relationship between financial and innovation systems. This relationship takes place asymmetrically with nascent and emerging firms as well with large corporations and it is the structure they belong to that influences their behavior.

4. Technological regimes and innovation patterns

Nelson and Winter (1982) introduced the concept of technological regimes to describe the technical environment in which firms operate. Technological regimes are cognitive structures that set boundaries for patterns of innovation activity. On the one hand, there is the 'science-based' regime within which technologies arise from universities and research centers, that is, outside a firm's boundary, while on the other we find the so-called 'accumulative technology' regime within which technologies emerge from the productive capacity of firms.

According to Nelson and Winter (1982), technological regimes define the nature of the problems surrounding innovation activity, shape the incentives and constraints on particular innovative behaviors of firms and affect the basic process of technology/product development and selection. They depend on the opportunities offered by the technological and scientific environments, the conditions of appropriability, and the nature of the knowledge developed and incorporated by the industry. It is observed, for example, that firms that experience the same learning structure tend to show similar patterns of innovation and competition.

In a later paper, Winter (1984) elaborates on *Schumpeter's Mark I and Schumpeter's Mark II* definitions and suggests two technological regimes: the entrepreneurial regime and the routinized regime. In the entrepreneurial regime, the innovative environment favors the entry of new and small firms. In the routine regime, the conditions are favorable to the concentration of innovation activity in the laboratories of large, established firms.

Based on the approach developed by Nelson and Winter (1982) and Winter (1984), several authors (Audretsch, 1991; Dosi *et al*, 1995; Kim and Lee, 2003; Dosi *et al*, 2021) have tried to establish a link between technological regimes and innovation patterns. Malerba and Orsenigo (1996, 1997) suggest that technological regimes consist of four elements: technological opportunities, appropriability, cumulativeness, and the nature of knowledge. On the other hand, innovation patterns derive from sectoral particularity and are characterized by the dynamics of 'creative destruction' (*Schumpeter Mark I*) and 'creative accumulation' (*Schumpeter Mark II*).

Technological opportunities reflect the likelihood that a firm will innovate considering its R&D spending. The greater the opportunities, the greater the incentive for firms to innovate and take advantage of a rich and growing knowledge base, facilitating the

entry of new firms. Appropriability determines the possibility of protecting innovation against imitation and appropriation of the profits derived from innovation activity through patents, industrial secrets, etc. Cumulativeness means that the innovative capacity of firms depends on accumulated knowledge, learning, and experience. Thus, "cumulative innovations" generate a sequence of innovations, which are either incremental innovations or radical ones (DIBIAGGIO; NASIRIYAR, 2008, p. 12). The nature of knowledge refers to the knowledge base behind the firms' innovative activities. As seen in Winter (1987) and Dosi (2006), this base will vary across industries and technologies because it depends on variables such as the level of specificity, tacitness, complementarity, and independence.

According to Breschi *et al* (2000) and Malerba (2004), those differences in the organization of innovation activity at the sectoral level are based on the fundamental distinction between *Schumpeter Mark I* and *Schumpeter Mark II*. The authors state that *Schumpeter Mark I* is surrounded by high technological opportunity, low appropriability, low cumulativeness of knowledge by firms, high entry rate, and high instability in the hierarchy of innovative firms. In contrast, *Schumpeter Mark II* is bounded by conditions of low opportunity, high appropriability, high cumulativeness of knowledge by firms, low rate of new entrants, and stability in the hierarchy of innovative firms.

It is important to note that those Schumpeterian technological regimes and patterns of innovation are not static, as they tend to change over time. When a new industry is developing, uncertainties are very high, technical and capital barriers for new entrants are low, and knowledge changes rapidly. In this scenario, new firms emerge as the principal agents of innovation. As the industry matures and technological changes follow well-defined trajectories, innovative protagonism becomes that of the large firms (UTTERBACK, 1994; KLEPPER, 1996). However, one may note that when technological discontinuities occur in a given industry, the *Schumpeter Mark II* pattern tends to be replaced by *Schumpeter Mark I* (CHRISTENSEN; ROSENBLOOM, 1995). That happens because disruptive technologies make dominant products obsolete and threaten the market leadership of established firms.

The specificities of technological regimes affect the social and material structure in which firms are embedded. Therefore, they affect the relationships established between firms and the sources of innovation financing. To understand how these characteristics of technological regimes and innovation patterns influence the interrelationship between finance and innovation, it is worth mentioning some particularities - already established in the evolutionary literature - of the sectoral innovation systems of two specific industries: semiconductors and biotechnology.

4.1 The semiconductor industry

Many opportunities flourished in the early years of the semiconductor industry. The basic science behind the discovery of the transistor was relatively easy to assimilate and it

attracted the attention of scientists, entrepreneurs, and large established firms, both from within and without the electronics industry (MALERBA; ORSENIGO, 1993). However, firms that gave rise to much of the industry's innovations were generally not those that successfully exploited these innovations in the marketplace (DOSI, 2006). Between 1950 and 1955, large, established firms in the electronics industry were responsible for 92% of all leading innovations (DOSI, 2006, p. 64). Furthemore, the antitrust policy of the U.S. government, which opened the patents of AT&T[2] related to semiconductors, led to a scenario of low appropriability and promoted significant changes in the development of the semiconductor industry (DOSI, 2006).

As the development of the integrated circuit (IC) – a combined series of transistors on a single silicon chip – the opportunities in the sector increased, which made it possible for new firms to enter the market and share the market with established firms. But unlike the transistor development period, the knowledge base that emerged with the IC "became more and more centered on design and engineering rather than on basic science, and became increasingly tacit and firm-specific" (MALERBA; ORSENIGO, 1993, p. 52). And the more tacit the technology became, the more routinized did the innovation.

The concern for national defense generated by World War II and the subsequent Cold War stimulated U.S. government spending on the acquisition of electronic components. The large volume of government purchases ensured demand for the industry and enabled a further advance in the learning curve of the firms. To meet the high demand and the specificities of military applications, firms had to invest in electronic components that grew increasingly smaller but offered higher performance and efficiency (DOSI, 2006). On the one hand, the U.S. government's public funding and financing policies facilitated technological access and diffusion, while on the other they helped intensify competition among firms in the market and created a rigorous and selective environment that helped eliminate the less efficient ones.

In general, when we analyze the semiconductor industry between 1953 to 1998 based on the patents filed at USPTO[3], we find there is a high cumulative nature of the firms' learning process and a low level of opportunities (DIBIAGGIO; NASIRIYAR, 2008). The increasing intensity of R&D activities in the sector (accounted for by the number of patents filed) has enabled the entry of new firms, but the contributions of these firms to technological advances in the industry have been lower than the contributions stemming from large firms that are already established in the market (DIBIAGGIO; NASIRIYAR, 2008; PELLENS; MALVA, 2018). Thus, the semiconductor industry is a routinized regime in which the *Schumpeter Mark II* pattern prevails.

[2] The first firm to develop the transistor.
[3] United States Patent and Trademark Office

4.2 The biotechnology industry

According to Pisano, biotechnology is “a body of knowledge and techniques for using live organisms in a particular productive process” (1991, p. 238). Its theoretical basis encompasses the connection of areas of knowledge such as biology, chemistry, medicine, and computer science. Thus, biotechnology has applications in health, agriculture, and several other industrial areas.

The origin of the biotechnology industry dates back to the founding of Genentech in 1976. Genentech was the first biotech firm to exploit the commercial potential of the new recombinant DNA technology (rDNA) discovery (McKELVEY et al, 2004). The rDNA and monoclonal antibody (MAb) drove the technological regime behind the first-generation of biotech firms. The novelty and pervasive purpose of those technologies spurred many new biotech firms (NBFs). Between 1976 and 1981, NBFs dominated the biotech landscape at the time (PISANO, 2006). In this period, few established firms (such as Monsanto, DuPont, and Eli Lilly) developed internal R&D programs in biotech. The vast majority of pharmaceutical and chemical firms started their programs from 1981 on. Although the large established firms had the structure needed to test, produce and commercialize new products, NBFs were predominant in the early years of the biotech industry (MALERBA; ORSENIGO, 1993).

The first NBFs were "virtual enterprise with no physical assets and full-time employees" (PISANO, 2006, p. 85). In general, NBFs had high technical skills but had little or no experience in producing for the market. They positioned themselves in the market as firms specialized in providing R&D services (PISANO, 2006). The adoption of this business model was due to the entry barriers of the pharmaceutical industry. In the mid-1970s, a firm interested in developing a new drug would need to invest around $1.7 billion over 10 to 12 years (PISANO, 2006, p. 85). There was no external source of capital willing to finance the long-term and the high cost investments that NBFs faced to enter the pharmaceutical sector at that time. Throughout the 1960 and 1970s, venture capitalists preferred to invest in new electronics firms rather than biotech firms (PISANO, 2006, p. 85).

The major innovation in the business model of the first-generation of biotech firms was the strategic alliance established between Genentech and the pharmaceutical giant Eli Lilly (which had the capital and manufacturing infrastructure). This alliance enabled Genentech to finance its recombinant DNA insulin program. In return, Eli Lilly had the right to produce and commercialize the insulin developed by Genentech (PISANO, 2006, p. 86). This model of vertical integration and R&D collaboration as a mode of funding quickly spread in the market.

Besides the strategic alliance, the successful public offering (IPO) of Genentech stock in 1981 opened a new path to finance NBFs (PISANO, 2006). Thousands of NBFs

emerged over the same decade, most of them backed by venture capital firms (TULUM; LAZONICK, 2019). According to data from the National Venture Capital Association (NVCA) published in 2013, VC organizations' investments in the biotech sector have grown from US$ 136 million, in 1985, to about US$ 4 billion, in 2012.

At last, large pharmaceutical firms have embraced corporate venture capital (CVC) as a strategy to finance innovation by purchasing shares in new firms. In this scenario, the window of opportunity to explore new technology remains open and attracting new generations of NBFs. In turn, the large established firms interested in appropriating the values generated by new opportunities continue to develop new partnership models with start-ups. Thus, as pointed out by Malerba (2005), these aspects suggest that the biotech sector fits into an entrepreneurial regime in which the *Schumpeter Mark I* pattern stands out.

5. The financing of innovation

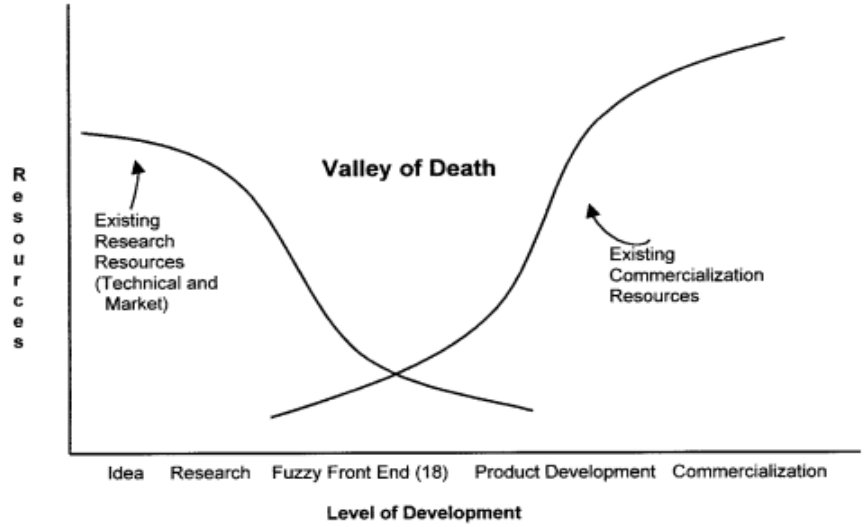
5.1 The uncertain path between financing innovation and the market

As discussed in the previous section, particularities of the sectoral innovation systems influence the dynamics of the innovation process between new and small firms and large ones. Such particularities affect and are affected by the financial agents that support the development of new technologies in each sector. So innovation financing is not neutral as it can affect the rate and the direction of innovation (MAZZUCATO; SEMIENIUK, 2017, p. 25). In this section, we argue that no matter whether the new technology comes from a technological-based firm or university, the path to the market is arduous most of the time. In the literature, this path is compared to a "valley of death" (MARKHAM, 2002) - Figure 1.

In a broader context, this valley of death reinforces the thesis that the innovation process is surrounded by a high degree of uncertainty. Even if firms have a reasonable idea about the standards (existing commercialization resources) that could determine the success of new technology, they cannot determine the market reality and the behavior of competitors before they start commercializing their products. Some technologies will be successful and may generate innovative products (or new firms). Others Technologies will be incorporated as improvements to existing products, while many others will fail to prove their value in the market. In the words of Freeman and Soete (2008, p. 415), "what can be seen ex-post cannot always be controlled or planned ex-ante"[4].

[4] Original Portuguese passage: “o que pode ser reconhecido ex-post nem sempre pode ser controlado neste ou iniciado ex-ante”.

FIGURE 1 – Valley of Death



Source: Markham (2002, p.32).

Besides technical and market uncertainties, economic uncertainties also affect innovation. As seen in Leonel *et al* (2012), financial agents prefer liquidity in a landscape of crises or when the market is more conservative. In that circumstances, illiquid assets (R&D) became less attractive than liquid ones (money). That occurs because the liquid asset's own interest rate becomes higher than the one offered by an innovative asset. Hence, credit for innovation becomes scarcer and, consequently, firms tend to postpone their investments in developing new products and services, expanding production, etc.

Further, R&D investments face some difficulties such as i) the production of intangible assets that are difficult to be evaluated; ii) volatility of market conditions – both in terms of the acceptability of products and services, and the availability of future credit supply (GOMPERS; LERNER, 2001); iii) indivisibility of knowledge; and iv) limited appropriability by its inventor. Those characteristics hamper *ex-ante* quantifications of costs and the potential profitability of innovative assets. They also inhibit external financing or trigger the underinvestment problem (ARROW, 1962).

Hall (2002) and Carpenter and Petersen (2002) also point out that R&D investments have some features that make them different from other types of investment, such as i) on average, 50% of the resources go to pay salaries of highly qualified professionals; ii) knowledge is tacit, meaning that it is not so easy to dismiss or replace a person involved with R&D without significant losses; iii) the investment time returns are long and uncertain, which increases the risk premium; and iv) the existence of information asymmetry hamper efforts to separate good projects from bad ones.

In this scenario, firms and financial agents have articulated themselves in many ways to foster and finance innovation. For instance, large knowledge-intensive firms have created dedicated departments to monitor and acquire new firms and technologies related to their knowledge base (GOMPERS; LERNER, 1998; IVANOV; XIE, 2010). But when internal R&D costs are higher than the transaction costs associated with market contracts, CVC has proven to be a good alternative for large firms (BRETEL, 2010). On the other hand, VC organization would be a possible light at the end of the tunnel to new and small firms.

In light of the above,

> […] it is of fundamental importance to understand how technologically creative individuals and firms obtain the resources needed to undertake their investment in invention and innovation. It is also important to understand how the availability of such resources, including the manner in which they are accessed as well as the amounts that can be raised, influences the rate, direction, and organization of technological development (LAMOREAUX; SOKOLOFF, 2007, p.3).

One suggestion to address Lamoreaux e Sokoloff's reflections would be to incorporate the relationship between the stages of innovative firm development and the sources of funding allocation into the evolutionary economy. Understanding this relationship is critical because a new innovative firm produces intangible assets that do not serve as collateral[5]. Therefore, they demand different kinds of financing mechanisms than those accessible to less knowledge-intensive firms.

5.2 The stages of innovative firm development and sources of capital

> It may be that most firms do not grow, that failure is more common than success, that over the long, long period, firms like Schumpeter's lemmings follow each other in succeeding waves into the sea and drown, or even that 'death and decay' are inherent in the structure of organization. These things we do not know. We have neither the facts to disprove them nor convincing theoretical presumptions to support them. (PENROSE, 2006 [1959], p. 73).

[5] Collateral includes securities, promissory notes, trade notes receivable, or real securities that are offered as collateral for a loan.

In *The Theory of the Growth of the Firm*, Edith Penrose studies the growth rate of firms from a business knowledge perspective. According to Penrose, the theory of the growth of the firm derives from an assessment made by firms on changes in productive opportunities (2006 [1959], p. 72). Besides Penrose's perspective, other approaches[6] emerge from the literature. One of them stands that a firm's organizational development process unfolds in sequential stages.

It is incorrect to assume that all types of firms will evolve following a linear model of stage development. As seen in Caves (1998), many firms will not outlive their first years of life, while others will develop into large corporations. In general, each firm will have its behavior shaped by the environment in which it operates. On the other hand, the definition of stages of development highlight some firm's behavior patterns.

In the same vein, the articles by Ruhnka and Young (1987) and Roberts (1991) give details on some patterns of behavior experienced by nascent and emerging technology-based firms throughout their developments. Below we present a systematization and adaptation of the contributions offered by those researchers. Here, the stages described by Ruhnka and Young and Roberts have been transformed into four stages: Seed, Start-up, Expansion, and Later Stage (Table 1).

Table 1 – Stages of development of the technology-based firm

Phase	Operational characteristcs	Financial constraints
Seed	● Technology development, proof of concept, and the first generation of prototypes; ● Preliminary market research; ● Few resources; ● No formal facilities; ● No management team; ● The risk is higher.	• Zero revenue; • Negative cash flow.
Start-up	● Modest facilities, and inexperienced management staff; ● No collateral to raise a loan; ● Firms need capital to finance product development and market expansion. They also need money to hire qualified employees; ● The risk is higher.	● Very low and fluctuating revenue; ● Negative cash flow.

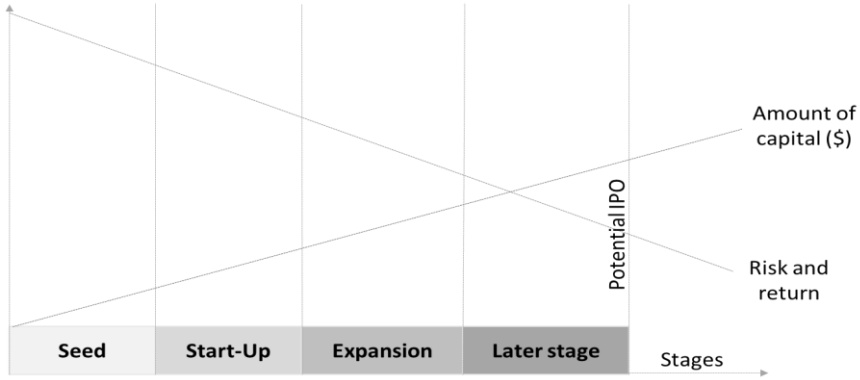
[6] See O'Farrell e Hitchens (1988), Gibb e Davies (1990), and Caves (1998).

Expansion	● Good earnings prospects; ● Low risks and business uncertainties; ● High demand and complexity of operations growth; ● Firm is profitable, but with resources below the needs to finance the development of new technologies.	● Firms reache operational breakeven; ● Revenue growth.
Later Stage	● Firms have the financial capital to finance; almost all demands. They also have collateral and a reputation to secure a loan; ● Potential to public stock.	● Revenue growth; ● Positive cash flow; ● Payment of dividends.

Source: Elaborated by the authors

This delimitation sheds light on the organizational process and financial demands faced by innovative firms throughout their development. At each stage of development, innovative firms experience distinct characteristics and needs for financial resources (Figure 2). One may see that as the firm develops, the need for financial resources also increases. In turn, the associated risks and the return expected by investors tend to decrease.

FIGURE 2 - Need for financial resources versus risk and return



Source: Elaborated by the authors

Those characteristics seem to influence the attitude towards risk, investment preference, and the selection criteria for the sources of financing accessible to innovative

firms. For example, private venture capitalists prefer to invest in sectors that offer short-term returns - usually from 3 to 5 years cycles. In many sectors, they enter only after decades of public investments (MAZZUCATO, 2018). As seen in Mazzucato (2018), this short-term perspective has caused problems in science-based industries, as the biotechnology sector. According to Mazzucato and Semieniuk (2017), science-based ones could benefit from long-term finance.

Based on empirical evidence, Bakker (2013, p. 1809) shows that a series of sources of capital to finance innovative projects emerged over time. He also points out that those sources can be divided according to small-scale or large-scale financing they provide and the stage in the R&D process they most easily finance. Roberts (1991) also describes the primary investment preference of seven sources of capital: personal savings; contributions from family and friends; private investors or angels; seed capital / VC organizations; small business investment companies (SBIC)[7]; family/high net worth funds; CVC; commercial banks; and public stock issues. Among them, seven sources are displayed in Table 2.

TABLE 2- Behavior of the sources of capital accessible to innovation

Fontes de capital	Start-up	Initial Growth	Sustained Growth	Primary Source of Initial Capital (n= 154 companies) (I)	Amount of Initial Capital ($ thousands) (II)
Personal Savings	X	X		114	<250
Family and Friends	X	X		8	<100
Angels	X	X		11	<500
Venture Capital	X	X	X	8	> ou = 500
Corporate Venture Capital	X	X	X	9	> ou = 500
Commercial Banks		X	X	0	0
Public Stock		X	X	4	> ou = 500

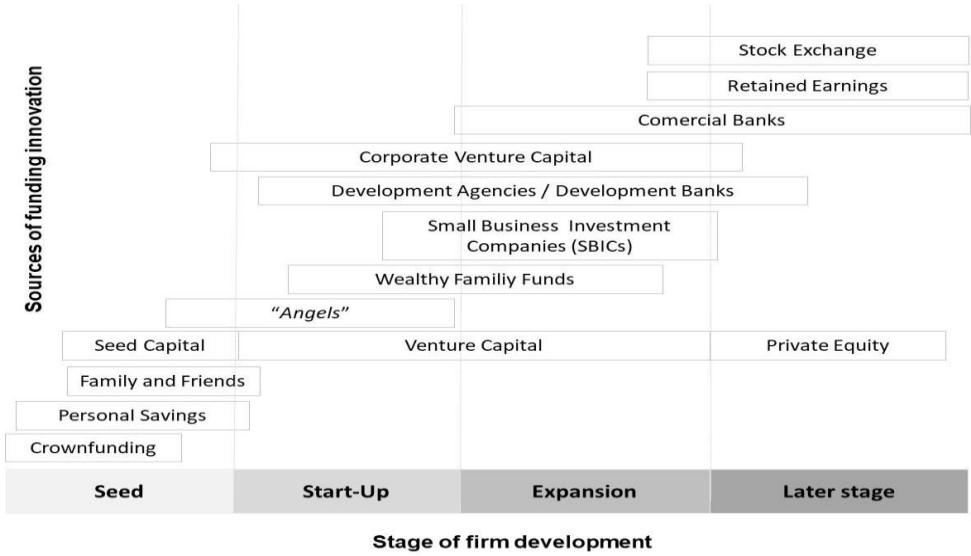
Notes: (I) results were obtained from a sample of 154 technology-based firms from various sectors / (II) results were obtained from a sample of 110 new technology-based firms.

Source: Adapted from Roberts (1991)

[7] According to Roberts (1991), SBIC is a special form of venture capital encouraged by the United States government. Investment firms receive tax incentives to finance small businesses. The investments are more pulverized, not only focusing on technology

The research conducted by Roberts with 154 technology-based firms shows that 114 firms turned to personal savings as their first source of capital. Angels, VC funds, and contributions from family and friends were the first source for 11 and 8 firms, respectively. The CVC financed the initial years of 11 firms, while the stock market was the first source of capital for four firms. Interestingly, no interviewed firm responded that they used commercial banks as their first source of capital. Among the sources mentioned, the contribution offered by VC firms, CVC, and the stock market was above or equal to US$ 500 thousand. The contribution from family and friends was less than US$100,000.
Figure 3 portrays the relationship between the sources of funding innovation and the stage of development of an innovative firm. The original proposal was expanded to include other sources such as crowdfunding, development agencies/development banks, private equity, and retained earnings. As listed in Figure 3, firms in the Expansion and Later Stage phases have access to a greater volume of credit supply than those in the Seed and Start-up phases. Among the reasons for this distortion, one can point out that the assets offered by a Seed or Start-up firm have low collateral value, revenues are low (or zero), and cash flow is negative. Therefore, this type of firm is not attractive to conventional sources such as commercial bank and do not fit the standards required for an IPO.

FIGURE 3 - Primary Preferences of Innovation Funding Sources



Source: Adapted from Roberts (1991, p. 155)

Although Figure 3 gives us a good perspective on the availability of capital from different sources, it is worth noting that the diagram is inexact, and the investment behavior

of each source may vary. It means that a given source which has a primary preference for firms at a particular stage of development may also finance firms at other stages. According to Hahn *et al* (2019, p. 354) "evidence suggests that startups seeking funding often rely on different financing sources simultaneously" and that there are complex relationships between venture capital and angel investors. Recent studies point out interconnections of various funding sources and links among established forms of innovation financing. The growing complexities of the entrepreneurial finance market appear, for example, in co-investments involving angels, venture capital, and crowdfunding (WALLMEROTH *et al*, 2018).

5.3 Different firms pursue different strategies

Firms have an innovation-seeking behavior as a means to survive. However, firms have different routines and will pursue different strategies to innovate. Those strategies are limited by the organization – organizational structure, production techniques, and so forth (NELSON; WINTER, 1982). As seen in the semiconductor and biotech industries, business organizations and the environment also affect investment decisions in funding innovation. Thus, differences in the organization of innovation activity at the sectoral level produce different financing demands. However, sectoral influence is not the only one shaping the relationship between finance and innovation.

> [F]our characteristics reveal much about the kind of finance that is needed. The uncertainty means that finance must be willing to bear high risks; the long-run nature of innovation and its cumulativeness imply that the kind of finance must be patient; and the collective nature means that there is not only one type of finance that is involved - but rather different forms, from a variety of public and private sources. Thus, it can be expected that *the type of finance received will affect the nature of investments made* (emphasis on original. MAZZUCATO; SEMIENIUK, 2017, p. 25).

The particularities of the innovation process at the micro-level also affect the relationship that firms will establish with their potential funding sources. Recall that the innovation process itself is surrounded by a high degree of uncertainty. Therefore, a firm cannot predict in advance the success and financial return of their R&D activities. Consequently, this affects the availability of accessible financial resources to firms because some sources of capital will be more willing to take risks, while others do not. On a macro-level, those four characteristics influence technological and economic development.

As discussed here, in each stage of development, innovative firms reveal distinct characteristics and demands for financial resources. Firms that are in the phases of

Expansion and Later Stage seem like Schumpeter's Mark II because when they need external finance they find it easily in commercial banks and the stock market. On the other hand, those in the Seed and Start-up struggle to find financial sources, a situation seen on Schumpeter's Mark I. In other words, firms in the Seed and Start-up stages are unlikely to access traditional sources of financing like commercial banks. In general, these firms have only intangible assets (patent, copyright, industrial secret, and so on) that do not secure bank loans. In this case, angels, crowdfunding, and VC organizations are the alternative for riskier investments.

Each funding source allocates its resources considering the stages of development of the innovative firm. At each stage of development, a firm outlines strategies for seeking financing, adapting routines according to its organizational structure. Understanding the particularities of these stages, the organization of innovation activity at the sectoral level, the choices for sources of financing, and the preference for sources of capital are essential for a complete understanding of the behavior of firms seeking funding for innovation.

6. Conclusion

The relationship between finance and innovation has been little addressed by evolutionary economists. As a result, numerous questions about the interrelationship between finance and innovation remain unexplored. This article sought to contribute to the evolutionary literature by emphasizing the dynamics of innovation financing through the characteristics that define sectoral innovation systems and the stage of firm development. This paper also emphasized two broad innovation systems operating in parallel in the economy, characterized as *Schumpeter Mark I* and *Schumpeter Mark II*. These sectoral patterns are influenced by technological opportunities, appropriability, cumulativeness, and the nature of knowledge. The prevalence of one system over the other or the coexistence within the same economic sector may be possible.

In short, understanding the behavior of innovative firms from an evolutionary perspective involves more than defining their preferences and the production function. Innovative firms confront a context of uncertainties in which the limited rationality of entrepreneurs and capitalists is constantly exposed. As might be expected from the discussion thus far, technological regimes and innovation patterns help understand that i) firm's behavior is not uniform or standardized, ii) there is no maximizing behavior, much less optimal choice, iii) the innovation process is uncertain, and iv) market's dynamics are led by disequilibrium and disruption. In this scenario, routines become guides to firm behavior, and the knowledge and learning acquired throughout the process shed light on new paths.

In addition, the stage of firm development illuminates the range of behavioral strategies used by innovative firms to learn and acquire knowledge and finance innovation.

Learning from those stages helps to understand that there are different sources of capital available, and they have their preferences to allocate financial capital through the stage of firm development. These preferences vary according to the risk and return of funding innovative firms.

Lastly, this paper discussed that, as the firm grows its financial resource requirements also increase while the risks associated with innovation and the return expected by investors tend to decrease. Thus, the opportunity to finance innovation differs across stage of development of the firm. To conclude, for each technological pattern and stage of development, a firm tends to present a different type of behavior in seeking financing for innovation.

References

ARROW, Kenneth. Economic welfare and the allocation of resources for R&D. In NELSON, Richard R. **The rate and direction of inventive activity**. Princeton, N. J.: Princeton University Press, 1962, p. 609-626.

AUDRETSCH, David Bruce. New-firm survival and the technological regime. **Review of Economics and Statistics**, v. 60, p. 441–450, 1991.

BAKKER, Gerben. Money for nothing: how firms have financed R&D-projects since the industrial revolution. **Research Policy**, v. 42, p. 1793–1814, 2013.

BRESCHI, Stefano; MALERBA, Franco; ORSENIGO, Luigi. Schumpeterian patterns of innovation and technological regimes. **The Economic Journal**, v. 110, n. 463. p. 388-410, 2000.

BRETEL, Malte. Corporate venture capital. In GERYBADZE, Alexander; HOMMEL, Ulrich; REINERS, Hans W; THOMASCHEWSKI, Dieter. **Innovation and international corporate growth**. Berlim: Springer-Verlag, 2010, p. 349-357.

CARPENTER, Robert; PETERSEN, Bruce. Capital market imperfections, high-tech investment, and new equity financing. **The Economic Journal**, v. 112, p. 54-72, 2002.

CAVES, Richard E. Industrial organization and new finding on the turnover and mobility of firms. **Journal of Economic Literature**, v. 36, p. 1.947-1.982, 1998.

COJOCARU, Laura; FALARIS, Evangelos M.; HOFFMAN, Saul D.; MILLER, Jeffrey B. Financial system development and economic growth in transition economies: New empirical evidence from the CEE and CIS countries. **Emerging Markets Finance and Trade**, v. 52, n.1, p. 223–236, 2016.

DIBIAGGIO, Ludovic; NASIRIYAR, Maryam. Technological regime and innovative pattern in the semiconductor industry. In **DRUID 25th Celebration Conference**, Copenhagen, CBS, Denmark, 2008, p. 1-33.

DOSI, Giovanni. Finance, innovation and industrial change. **Journal of Economic Behavior and Organization**, v. 13, p. 299-319, 1990.

DOSI, Giovanni. **Mudança técnica e transformação industrial: a teoria e uma aplicação à indústria dos semicondutores.** Campinas, SP: Editora da Unicamp, 2006.

DOSI, Giovanni; MARSILI, Orietta; ORSENIGO, Luigi; SALVATORE, Roberta. Learning, market selection and the evolution of industrial structures. **Small Business Economics**, v. 7, p. 411-436, 1995.

DOSI, Giovanni; PIVA, Mariacristina; VIRGILLITO, Maria Enrica; VIVARELLI, Marco. Embodied and disembodied technological change: The sectoral patterns of job-creation and job-destruction. **Research Policy**, v.50, n.4, 2021.

FREEMAN, Christopher. **Technology policy and economic performance: lessons from Japan**. London: Frances Pinter, 1987.

FREEMAN, Christopher; PEREZ, Carlota. Structural crisis of adjustment: business cycles and investment behavior. In DOSI, Giovanni; FREEMAN, Christopher; NELSON, Richard R. **Technical change and economic theory**. London: Pinter, 1988, p. 38-66.

FREEMAN, Christopher; SOETE, Luc. **A economia da inovação industrial**. Campinas: Unicamp, 2008.

GOMPERS, Paul A.; LERNER, Josh. The determinants of corporate venture capital success: organizational structure, incentives, and complementarities [Working paper 6725]. **National Bureau of Economic Research**, 1998.

GOMPERS, Paul A.; LERNER, Josh. **The money of invention: how venture capital creates new wealth.** Boston: Harvard Business School Press, 2001.

GERSCHENKRON, Alexander. **Economic backwardness in historical perspective**. Cambridge, MA: Harvard University Press, 1962.

GIBB, Allan A; DAVIES, Les G. In pursuit of frameworks for the development of growth models of the small business. **International Small Business Journal**, v. 9, n. 1, p. 15-31, 1990.

GRILLI, Luca; MAZZUCATO, Mariana; MEOLI, Michele; SCELLATO, Giuseppe. Sowing the seeds of the future: Policies for financing tomorrow's innovations. **Technological Forecasting and Social Change**, v.127, p. 1-7, 2018.

HAHN, Davide; MINOLA, Tommaso; VISMARA, Silvio; DE STASIO Vincenzo. Financing Innovation: challenges, opportunities, and trends. **Foundations and Trends in Entrepreneurship**, v. 15, n. 3-4, p. 328–367, 2019.

HALL, Bronwyn H. The financing of research and development. **Oxford Review of Economic Policy**, v. 18, n. 1, p. 35-51, 2002.

IVANOV, Vladimir I.; XIE, Fei. Corporate venture capital. In CUMMING, Douglas. **Venture capital: investment, strategies, structures, and policies**. John Willey & Sons, Inc., Hoboken, New Jersey, 2010, p. 51-70.

KIM, Chang-Wook; LEE, Keun. Innovation, technological regimes and organizational selection in industry evolution: a 'history friendly model' of the DRAM industry. **Industrial and Corporate Change**, v. 12, n. 6, p. 1195-1221, 2003.

KING, Robert; LEVINE, Ross. Finance and growth: Schumpeter might be right. **Quartelry Journal of Economics**, v. 108, n. 3 p. 717-737, 1993.

LAMOREAUX, Naomi R.; SOKOLOFF, Kenneth L. **Financing innovation in the United States, 1870 to the present**. Cambridge, Massachussetts: The MIT Press, 2007.

LEONEL, Solange G.; MARQUES, Sylvia F.; SANTOS, Ester C.; RESENDE, Marco Flávio C. Understanding financial innovation systems: Veblen and Minsky at the periphery. **European Journal of Economics and Economic Policies**, v.10, n. 1, p. 93-105, 2012.

LEVINE, Ross. Financial development and economic growth: views and agenda. **Journal of Economic Literature**, v. 35, p. 688-726, 1997.

LEVINE, Ross; ZERVOS, Sara. Stock markets, banks and economic growth. **American Economic Review**, v. 88, n.3, p. 537-558, 1998.

LUNDVALL, Bengt-Ake. **National systems of innovation: towards a theory of innovation and interactive learning**. London: Anthem Press, 1992.

MALERBA, Franco. **Sectorial systems of innovation: concepts, issues and analyses of six major sectors in Europe**. Cambridge University Press, 2004.

MALERBA, Franco; ORSENIGO, Luigi. Technological regimes and firm behavior. **Industrial and Corporate Change**, v. 2, n. 1, p. 45-71, 1993.

MALERBA, Franco; ORSENIGO, Luigi. Schumpeterian patterns of innovation are technology-specific. **Research Policy**, v. 25, p. 451-78, 1996.

MALERBA, Franco; ORSENIGO, Luigi. Technological regimes and sectoral patterns of innovative activities. **Industrial and Corporate Change**, v. 6, n.1, p. 83-117, 1997.

MARKHAM, Stephen K. Moving technologies from lab to market. **Research-Technology Management**, v. 45, n.6, p. 31– 42, 2002.

MAZZUCATO, Mariana. Financing Innovation: Creative Destruction vs. Destructive Creation." **Industrial and Corporate Change**, v. 22, n. 4, p.869–901, 2013.

MAZZUCATO, Mariana. Mission-oriented innovation policies: challenges and opportunities. **Industrial and Corporate Change**, v. 27, n. 5, p.803–815, 2018.

MAZZUCATO, Mariana; SEMIENIUK, Gregor. Public financing of innovation: new questions. **Oxford Review of Economic Policy**, v. 33, n. 1, p. 24–48, 2017.

McKELVEY, Maureen; ORSENIGO, Luigi; PAMMOLLI, Fabio. Phamaceuticals analyzed through the lens of a sectoral innovation system. In MALERBA, Franco. **Sectorial systems of innovation: concepts, issues and analyses of six major sectors in Europe**. Cambridge University Press, 2004, p. 73-120.

NVCA - NATIONAL VENTURE CAPITAL ASSOCIATION [Corporate venture capital]. Available in http://www.nvca.org/index.php?option=com_docman&task=cat_view&gid=99&Itemid=317. Last access: jan 24th. 2014.

NELSON, Richard R. **National innovation systems: a comparative analysis**. New York, USA: Oxford University Press, 1993.

NELSON, Richard R.; DOSI, Giovanni; HELFAT, Constance E; PYKA, Andreas; SAVIOTI, Pier Paolo; LEE, Keun; MALERBA, Franco; WINTER, Sidney. **Modern evolutionary economics: an overview.** Cambridge, UK; New York, NY: Cambridge University Press, 2018.

NELSON, Richard R.; WINTER, Sidney. **An evolutionary theory of economic change**. Cambridge, MA: Havard University Press, 1982.

O'FARRELL, Patrick N; HITCHENS, David M.W.N. Alternative theories of small-firm growth: a critical review. **Environment and Planning A**, v. 20, n. 2, p. 1365-1383, 1988.

O'SULLIVAN, Mary. Finance and innovation. In FAGERBERG, Jan; MOWERY, David C.; NELSON, Richard R. **The oxford handbook of innovation**. Oxford: Oxford University, 2005, p. 240-265.

PELLENS, Maikel; MALVA, Antonio D. Corporate science, firm value, and vertical specialization: Evidence from the semiconductor industry. **Industrial and Corporate Change** v. 27, n. 3, p. 489–505, 2018.

PAN, Lei; MISHRA, Vinod. Stock market development and economic growth: Empirical evidence from China. **Economic Modelling**, v.68, p. 661-673, 2018.

PENROSE, Edith [1959]. **A teoria do crescimento da firma**. Campinas, SP: Editora Unicamp, 2006.

PEREZ, Carlota. **Technological revolutions and financial capital**. Cheltenhm: Edward Elgar, 2002.

PISANO, Gary. The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry. **Research Policy**, v. 20, p. 237–249, 1991.

PISANO, Gary. **Science business: the promise, the reality and the future of biotech**. Boston: Harvard Business School Press, 2006.

ROBERTS, Edward B. **Entrepreneurs in high technology: lessons from MIT and beyond.** New York, USA: Oxford University Press, 1991.

RUHNKA, John C.; YOUNG, John E. A venture capital model of the development process for new ventures. **Journal of Business Venturing**, v.2, p. 167-184, 1987.

SCHUMPETER, Joseph. **Business cycles**. New York: McGraw Hill, 1939.

SCHUMPETER, Joseph. **Capitalism, socialism, and democracy**. New York: Harper & Brothers, 1942.

SCHUMPETER, Joseph [1911]. **The theory of economic development: an inquiry into profit, capital, credit, interest, and the business cycle**. New Brunswick: Transaction Publishers, 16 ed., 2012.

SHIOWAZA, Yoshinoni. 'Microfundations of Evolutionary Economics'. In SHIOWAZA, Yoshinoni; MORIOTA, Masashi; TANIGUCHI, Kazuhisa. **Microfundations of evolutionary economics.** Evolutionary Economics and Social Complexity Science. Volume 15. Japão: Ed. Springer, 2019.

TULUM, ÖneR; LAZONICK, William. Financialized Corporations in a National Innovation System: The U.S. Pharmaceutical Industry. **International Journal of Political Economy**, v. 47, n.3-4, p.281-316, 2018.

VEBLEN, Thorstein. **The place of science in modern civilizations and other essays**. New York: Russel & Russel, 1961.

WALLMEROTH, Johannes; WIRTZ, Peter; GROH, Alexander. Venture capital, angel financing, and crowdfunding of entrepreneurial ventures: a literature review. **Foundations and Trends in Entrepreneurship**, v.14, n.1, p. 1–129, 2018.

WINTER, Sidney G. Schumpeterian competition in alternative technological regimes. **Journal of Economic Behavior and Organization**, v. 5 (3-4), n. 13, p. 421-440, 1984.

WINTER, Sidney G. Knowledge and competences as strategic assets. In TEECE, David J. **The competitive challenge**. Ballinger. Cambridge, 1987, p. 159-184.

ZYSMAN, John. **Goverments, markets and growth: financial systems and politics of industrial change**. Ithaca & London: Cornell University Press, 1983, p. 55-95.