DOI: https://doi.org/10.14393/REE-v37nesp. ago.a2022-66689
Instituto de Economia e Relações Internacionais – Universidade Federal de Uberlândia

economia
ensaios

Evolutionary economics matters: an overview of the extraordinary contributions of Nelson & Winter

A importância da economia evolucionária: um panorama das extraordinárias contribuições de Nelson & Winter

Germano Mendes de Paula [a]
Marisa dos Reis Azevedo Botelho [b]

Resumo: Este artigo tem como objetivo analisar algumas das principais contribuições sobre economia evolucionária e inovação feitas por Richard Nelson e Sidney Winter. Revisamos, em especial, as principais questões abordadas nos livros publicados em 1982, como busca, rotina e seleção, e 2018, como os novos e importantes elementos do debate que ainda são pouco abordados pela teoria evolucionária. Também nos concentramos nas diferenças discricionárias das empresas e nos mecanismos de apropriabilidade, que são temas relacionados aos níveis setorial e empresarial, e investigamos a relação entre ciência, inovação e desenvolvimento econômico, que são temas em nível macro.

Palavras-chave: Economia Evolucionária, Desenvolvimento Econômico. Ciência e Tecnologia, Inovação.
Classificação JEL: O30, O10.

Abstract: This review article aims to analyze some of the main contributions regarding evolutionary economics and innovation made by Richard Nelson and Sidney Winter. We reviewed, in particular, the main issues covered in the books published in 1982, such as search, routine, and selection, and 2018, such as the new and important elements of the debate that are still poorly addressed by evolutionary theory. We also focus on the discretionary firm differences and the mechanisms of appropriability, which are themes related to sector and company levels, and investigate the relationship between science, innovation, and economic development, which are themes at macro level.

Keywords: Evolutionary Economics, Economic Development, Science and Technology, Innovation.
JEL Classification: O30, O10.

[a] Professor Titular do Instituto de Economia e Relações Internacionais da Universidade Federal de Uberlândia. E-mail: germano@ufu.br.
[b] Professora Titular do Instituto de Economia e Relações Internacionais da Universidade Federal de Uberlândia. E-mail: botelhomr@ufu.br.

Introduction

In 1982, Richard Nelson and Sidney Winter published the book intitled "An evolutionary theory of economic change", which a was landmark regarding the so-called "evolutionary economy". To celebrate the 40th anniversary of this seminal contribution, we organized this special issue containing ten articles, besides this introduction. The preface was written by Richard Nelson himself, who is currently Professor Emeritus at the Columbia University, New York.

Professors Nelson and Winter (NW, thereafter) have prolific academic contributions indeed and examining a large proportion of this contribution is far beyond the scope of this review. In fact, we prefer to emphasize what we understand to be the crucial features of this long and ongoing literature. The first section is dedicated to discussing the major ideas developed in their 1982's book. The second section analyzed the discretionary firm differences, whereas the following section focused on the mechanisms of appropriability. The fourth section focusses on the relationship between science, innovation, and economic development, highlighting Nelson's works in the 2000's. The fifth section scrutinizes the key ideas debated in the book "Modern evolutionary economics: An overview" that was published in 2018. The final section summarizes the main conclusions of this review article.

1. The construction of evolutionary theory: the publication of the book "An evolutionary theory of economic change"

This section presents the main contributions of the book "An evolutionary theory of economic change," authored by NW, which is celebrating 40 years of publication this year.

According to the authors, the construction process of this important piece took place over a decade of cooperative work. This partnership resulted in more than a dozen of articles presented in various Universities in the United States and Europe and published in specialized scientific journals. Given the long, broad, and in-depth elaboration process, understanding why this book has become a mandatory reference for the knowledge of the Neo-Schumpeterian approach is possible.

However, note that the article intitled "In search of useful theory of innovation", which was published in 1977, had already contained some of the main contribution that was analyzed in depth in the book. In the article, the authors pointed out the need to consider the competitive process based on the selection environment and the generation and diffusion of innovations confronting the neoclassical concept of equilibrium, in addition to carrying out an empirical analysis on the growth of productivity in the industrial sector during the 1948-1966 period. Thus, they introduced alternative and critical factors to the neoclassical theory, breaking with the concept of profit maximization of firms and agents' rationality. Moreover, they introduced features conforming a theory of innovation in which

the institutional environment is heterogeneous and is part of the selection environment, which matters to explain the different behaviors of firms and industrial sectors.

> *"For example, the 'selection environment' language seems useful for describing some of the important institutional differences among sector, and for beginning to explore some of the consequences of these for the inter-industry productivity growth puzzle. Clearly there is considerable variation among sectors in their 'selection' environments, and these differences can affect both the speed and extent of spread of any innovation" (NELSON; WINTER, 1977, p.277).*

In 1982 NW proposed to systematize an analysis of the role of technical progress in the competition process, proposing relevant ruptures from the treatment given to the subject from the perspective of conventional microeconomics. Thus, they build a critical approach to neoclassical theory, founding the debate on the existence of concepts such as equilibrium and maximizing agent, as they had already discussed in previous contributions.

We argue that the models built by the authors throughout the book aim to comprehend the different angles of economic change, namely: the behavior of firms in response to changes in the market, the logic of economic growth, and the competition based on innovation.

The authors begin the book by offering their motivations and the theoretical-organizational foundations of evolutionary economic theory in contrast to the concepts that underlie neoclassical microeconomic theory. Among the main motivations is the interest in demonstrating that firms aim to increase profits. Indeed, they are endowed with capabilities and rules for decision making, but unlike what the neoclassical theory proposes, they would not have a maximizing behavior.

> *"In an evolutionary theory of the sort we develop, the nature of the 'economic problem' is fundamentally different from that depicted in contemporary orthodox theory. The latter views choice sets are known and given. The economic problem is to pick the best possible production and distribution, given that set of alternatives. The function of competition is to get – or help to get – the signals and incentives right. In evolutionary theory, choice sets are not given and the consequences of any choice are unknown" (NELSON; WINTER, 1982, p. 276).*

Another aspect that deserves attention and that distances them from the orthodox perspective refers to the latter utilizing the *ceteris paribus* assumption. NW, on the contrary, focused on the change in the firms' behavior over time since these capabilities and their decision making can change. They, then, introduced the concepts of search, routine, and selection. From this perspective, the routine stands out as one of the main pillars of theoretical construction, which can be defined as follows:

> *"Our general term for all the regular and predictable behavioral patterns of firms is 'routine'. We use this term to include characteristics of firms that range from well-specified technical routines for producing things, procedures for hiring and firing, ordering new inventory, or stepping up production of items in high demand, to policies regarding investment, research and development (R&D), or advertising, and business strategies about product diversification and overseas investment. In our evolutionary theory, these routines play the role that genes play in biological evolutionary theory" (NELSON; WINTER, 1982, p. 14).*

Based on this concept, NW (1982) point out that routine plays an important role for the innovative development of firms. In fact, they highlight three roles it plays: routine as the organization's memory, routine as a truce, and routine as a goal.

Firstly, routine can be said to play the role of being the memory of the organization. The suggestion is that the routinization of activities is an important mechanism for accumulating the firm's own knowledge. In addition, coordination is necessary to integrate the various tacit knowledge.

Secondly, the role of routine for innovation refers to a truce regarding the internal conflicts of the firm. A clear understanding of the roles of each member of the firm disciplines the dispute and reduces potential conflicts. "*There is a truce between the supervisor and those supervised at every level in the organizational hierarchy. (...) There is, similarly, a truce in the struggle for advancement, power and perquisites among high-level executives*" (NELSON; WINTER, 1982, p. 110).

Thirdly, routine can act as a goal that influences innovation. The authors point out that maintaining a regular routine in operation is difficult and, therefore, the routine becomes a goal. "*When this is the case, the routine (in its smoothly functioning version) takes on the quality of a norm or target, and managers concern themselves with trying to deal with actual or threatened disruptions of the routine. That is, they try to keep the routine under control*" (NELSON; WINTER, 1982, p. 112).

Parts III and IV of the book present a critical discussion of the neoclassical theory of economic growth. NW proposed an evolutionary model of economic growth, based on the concepts of search, routine, and selection. Moreover, the discussions (and published articles) that preceded the 1982's book comprise several works dedicated to examine the growth theories, especially in the search to elaborating a macroeconomic growth model critical to the classical one proposed by Solow (1957). Concerning the construction of an alternative model, the authors propose an analysis of economic dynamics, breaking away with foundations defended by neoclassical theory.

By considering competition as a dynamic element, NW suggest that the number of firms and their ability to set prices is largely determined by a selection process that defines winners and losers. In other words, the companies that remain and those that are excluded from the market. In this context, the combination of search, routine, and selection elements

stands out. In addition to continuously searching for new production techniques, already consolidated routines related to the experience accumulated over time are present.

Assuming that the behavior of firms is heterogeneous, especially regarding understanding market signals and, consequently, adopting strategic decisions, the outcome is the enterprises acting differently. In this environment, competition plays an important role in the winner selection process that, in turn, results in a situation of continuous change/mutation.

The final parts of the book study a discussion of Schumpeterian competition, based on innovation, and the role of technical progress. It ends by examining the role of public policies.

> *"Our discussion of government policy toward R&D is similarly a starting point for further inquiry. It reveals some of the subtlety of the problems involved in using policy tools to amplify and modify the private incentives to create new technologies. The importance of the stakes, the diversity of industrial situations, and the complexity of the technical issues all combine to suggest that, in the future as in the past, policy interventions relating to R&D will be numerous, diverse and situation-specific" (NELSON; WINTER, 1982, p. 413).*

Based on the discussion of the seminal contribution of NW (1982), this review-article focusses on the following sections on in-depth studies on prominent themes in the authors' publication over time. The next section will emphasize the debate on science, technology, and economic development.

2. The sources and the significance of interfirm differences

Nelson published a classical article denominated "Why do firms differ, and how does it matter?," in a special issue of the "Strategic Management Journal" in 1991. Its main conclusion can be recapitulated as followed:

> *"Students of firm management, in particular those working in the strategy field, treat discretionary firm differences as their bread and butter. Economists have tended to play down these differences, or to argue that they are the result not the cause of general economic differences. In good part the difference in viewpoints is due to differences in basic interests – the student of firm management concerned with the fate of individual firms, and the economist interested in general economic performance of an industry or nation. But I have argued that the lack of interest by economists in discretionary firm differences stems as well from a particular theoretical view of economic activity and the role and behavior of firms.*
>
> *If one takes an evolutionary rather than a neoclassical view of what economic activity is about, then firm differences matter importantly regarding issues that traditionally have been the*

> *central concern of economists. Competition can be seen as not merely about incentives and pressures to keep prices in line with minimal feasible costs, and to keep firms operating at low costs, but, much more important, about exploring new potentially better ways of doing things" (NELSON, 1991, p. 72).*

Bearing this main message in mind, let's focus on some aspects highlighted by Nelson. He argued that economists tend to ignore discretionary firm differences and, consequently, the dissimilar choices made by the companies. Part of this tendency can be attributed to economists being more interested in broader aggregates (the whole economy or even a particular industry) rather than looking at the level of enterprises. However, this explanation seems insufficient to explain the entire picture. In fact, he stressed that the neoclassical economic theory, which provides the conventional wisdom for the profession, is badly limited for ignoring the discretionary firm differences.

Nelson observed that, typically, economists committed to a theory of firm behavior that postulated that the company faces given and known choice sets, constrained by available technologies. In this context, the enterprises do not have difficulties for making the best choice, by maximizing profits. Obviously, these assumptions are extremely far from the reality met by the firms, in particular those engaged in high tech industries.

Nelson recognized that economists made certain efforts to look inside the firm. Nonetheless, the ultimate reason for why companies differ continued to be rather superficial, since implicitly they assumed that the enterprises varied due to some initial conditions, such as operating in different industries or countries. However, what is key is examining how enterprise conducts are diverse within a given industry, therefore, the concept of strategy.

Nelson studied the role of innovation and firms in the evolutionary theory. He emphasized that the dynamic process described by Schumpeter (1984), are not captured by the (new) neoclassical models. Regarding the creative destruction development, there are winners and losers, and these outcomes are not determined in *ex-ante* calculation, but largely in *ex-post* actual contest. According to Nelson (1991), the concept of strategy implies a set of broad commitments from a company that define and rationalize its objectives and how it intends to pursue them. Believing *a priori* that these commitments are in fact optimal or even not self-destructive is baseless.

In a world based on creative destruction, the company's survival depends on its ability to innovate, and to make innovations profitable, again and again. Nelson (1991, p. 68) stressed that: "*Firms need to learn to get good at certain kinds of innovation, and at the things needed to take advantage of these, and this requires concentration or at least coherency, rather than random spreading of efforts*". Therefore, he emphasized the need of a reasonably coherent strategy, concerning the decision about what new ventures to invest. In that sense, he shared a similar view with Penrose (1959).

Since companies' strategies and associated capabilities differ significantly, the patterns of innovation are likely to vary meaningfully as well. For that reason, there are multiple rivalrous sources of new technology. In addition, when one enterprise comes up with a successful innovation, its competitors may differ sharply among themselves in their ability to imitate or develop something comparable in an effective way. Indeed, the ability to imitate also diverge among firms, since it would be easier for those companies with similar strategies and core competences.

Looking at the successful innovator companies, Nelson stressed that the organizational dissimilarities, mainly those related to the abilities to generate and gain from innovation, rather than differences in command over particular technologies, are the source of durable, not easily imitable, distinctions among enterprises. Obviously, he had a lot in common with the resource-based view (RBV).

In 2008, Nelson revisited the theme of discretionary firm differences. The rest of this section is mostly based on it. He reinforced attention to the heterogeneity within a given industry. Indeed, he observed that an economic section in even the finest cut evidently contains a variety of different kinds of firms, in diverse circumstances, catering to dissimilar groups of customers, and doing different things.

Nelson (2008, p. 612) declared that: *"Particularly in parts of the economy where there is significant product differentiation, it is conceptually impossible to define sharp disjoined industry categories based on markets".* He affirmed that a significant amount of the differences among firms in a nominal industry reflects the fact that diverse companies are serving dissimilar needs and different groups of customers. According to him, Schumpeter's characterization of competition in industries where product innovation is important implicitly denied the sharpness of industry boundaries. Likewise, the fact that clients often differ in what they want of a product and hence what competes with what is recognized.

Regarding Alfred Marshall, Nelson showed that some of his contributions have similarities with the evolutionary economics. Concerning this issue, he emphasized that:

> *"I think it highly relevant for the discussion we are having here that Marshall as an economic theorist — evolutionary, neoclassical, or both — clearly believed that the economic reality was too complex for mathematics to be the appropriate language for economic theory, at least of the level of abstraction that Sidney Winter and I have called appreciative theory" (NELSON, 2008, p. 610).*

Remember that appreciative theory refers to the conceptual approaches derived from empirical observations and regularities, instead of deduced from formal theory. It provides both guidance and interpretation and is mostly expressed verbally (NELSON, 1994).

Nelson argued that identifying and analyzing new entrants to an industry ought to be given special attention. In his opinion, the variety and turbulence in an economic sector at any time is connected to the relative importance of new entrants and their characteristics. As previously explored by Schumpeter, the continuing innovation as the key driving force behind economic change and the reason for enduring disequilibrium. Noticeably, this idea is extremely far from the neoclassical models.

Research on industrial innovation differs significantly among sectors, in terms of rates and types of innovation. For instance, they varied the importance of product and process innovation. In some industries most of the innovation comes from incumbents, whereas in others, newcomers played a crucial rule. Therefore, concluding that the critical factors behind differences among firms in an industry at any time, and the consequences of those variances, are not the same in all sectors is reasonable. Again, the heterogeneity among sectors is another key factor that shows a long distance from the orthodox economic view.

In the last paragraphs of this article, Nelson examined the relationship between interfirm differences and the "technological regime" or "technological paradigm" (concept developed by Dosi, 1983):

> *"In some of these industries, the paradigm may be relatively loose, leaving considerable room for differences among firms in what they think are the practices, including policies towards innovation, that are going to prove to be profitable. One would expect to see in such industries a reasonable amount of firm variety, including significant differences among firms at any time in their efficiency and profitability. (...)*
>
> *However, in industries where the technological paradigm is strong, the importance of competition is largely to spur firms to continuingly advance their technologies, or lose out to their more innovative colleagues. However, I would propose that the importance of competition in generating variety in such industries is less than in industries where the paradigm is looser" (NELSON, 2008, p. 617-618).*

Summing up, Nelson highlighted the need to scrutinize not only the variances among sectors, but also the differences among firms. In other words, company's strategy must be an essential part of industrial economics.

3. The mechanisms of appropriability

Appropriability refers to the strategy for appropriating the gains (profits) from a successful innovation. Part of these gains can be captured by the innovators, part by the competitors (who imitated or reached similar outcomes on their own), and part by suppliers

and customers. So, the idea is to investigate how the innovators can grab a large proportion of the extraordinary profits.

NW examined the issue of appropriability in different occasions, sometimes with different co-authors. The main conclusion of these articles can be summarized as follows:

> *"We find that firms typically protect the profits due to invention with a range of mechanisms, including patents, secrecy, lead time advantages and the use of complementary marketing and manufacturing capabilities. Of these mechanisms, however, patents tend to be the least emphasized by firms in the majority of manufacturing industries, and secrecy and lead time tend to be emphasized most heavily" (COHEN; NELSON; WALSH, 2000, p. 2).*

In other words, NW and their co-authors criticized the assumption that patents and other legal tools are the best and the most employed mechanism by manufacturing firms to retain the economic gains derived from innovation. Let's initially look at the article "Appropriating the returns from industrial research and development", which was written by Richard Levin, Alvin Klerorick, Richard Nelson, and Sidney Winter in 1987. Levin et al. observed that:

> *"Patent law seeks to resolve this tension between incentives for innovation and widespread diffusion of benefits. A patent confers, in theory, perfect appropriability (monopoly of the invention) for a limited time in return for a public disclosure that ensures, again in theory, widespread diffusion of benefits when the patent expires.*
>
> *Previous investigations of the system suggest that patents do not always work in practice as they do in theory. On the one hand, appropriability is not perfect. Many patents can be circumvented; others provide little protection because of stringent legal requirements for proof that they are valid or that they are being infringed. On the other hand, public disclosure does not always ensure ultimate diffusion of an invention on competitive terms" (LEVIN et al., 1987, p. 783-784).*

Levin et al. (1987) describe the outcomes of an inquiry into appropriability conditions in more than one hundred manufacturing industries, by emphasizing differences between process and product innovations. Similarly to others contributions by NW, the focus was on the asymmetries. The data was derived from a survey of high-level R&D executives, who informed opinions about relevant technology and market conditions rather than quantitative measures of inputs and outputs. They investigated six methods of appropriability: a) patents to prevent duplication, b) patents to secure royalty income, c) secrecy, d) lead time, e) moving quickly down the learning curve, f) sales or service efforts. Nelson (2000) also examined the first four tools.

As mentioned, the main contribution of Levin et al. (1987) was proving the limited effectiveness of patents as a means of appropriability, excluding some exceptions, such as

the pharmaceutical industry. This conclusion was further examined by Nelson (2000), who discussed four major classes of such mechanisms: a) patent and related legal protections, b) secrecy, c) control of complementary assets, d) lead time. According to him, these tools are neither mutually exclusive, nor fully exhaustive. In fact, they often are complementary approaches.

Winter analyzed at first the mechanism of patent and related legal protections. An innovation's patent will be able to keep competition out and generate huge profits. In fact, this assumption is true in some instance, since patent protection has been quite powerful for inventions related to the early development of new technology-based industries. However, it rarely serves to build a long-term successful business strategy, since: a) the legal cost of patent protection can be high, with part of the rents being appropriated by lawyers and legal costs; b) the effectiveness varies widely across industries, therefore interindustry differences matter; c) the possibility that competitor can legally "invent around". Moreover, even with the patent in place, the protection may be inefficient, due to the new developments by competitors. Imitation gaps of less than five years are common, and patent protection lasts twenty years.

The second mechanism, secrecy, is another way to deter competitors from knowing about or competing against your product. According to Nelson:

> *"Protecting innovative products through secrecy is difficult. Aspiring imitators often can acquire the product – either by posing as legitimate customers or by inducing legitimate customers to pass along the product or information about it – and then reverse-engineer it. This vulnerability typically emerges only after the product is available in the market, which gives the innovator the advantage of lead time, particularly if secrecy is maintained during product development" (NELSON, 2000, p. 251).*

Nelson highlighted that, in general, due to the possibility of reverse engineering, keeping secrets about products is more difficult than about processes. Furthermore, keeping a secret is easier when a "private code" is required or when it is too large, complex, and articulated to be transferred easily. Thus, he is focusing on the advantages derived from the tacit knowledge for appropriability.

Complementary assets include resources and competences such as access to distribution, service capability, customer relationships, supplier relationships, and complementary products. The company that controls these tangible and intangible assets may be more likely to benefit commercially from the innovation. According to Winter, the most powerful role of complementary assets is not the appropriability regarding a single innovation but across a wide range of innovations.

Winter mentioned that a survey conducted by Carnegie Mellon University concluded that "lead time" (or getting the right product to the market first) is the most effective

appropriability mechanism for product innovations, slightly higher than secrecy. Nonetheless, he stressed that like other mechanisms, variation across industries concerning the effectiveness of lead time is substantial. Lead time is longer if the company is a market maker or if combined with other innovative advantages of the leader. It can be coupled with learning capabilities to appropriate gains from innovations for longer periods. At this point, Winter showed proximity with the contributions of Teece and Pisano (1994) on the dynamic capabilities of firms.

The main contribution of Winter (2000) is that four mechanisms should be considered and utilized jointly to appropriate gains from emerging technologies. He observed that uncertainty tends to be pervasive in industries based on emerging technologies and appropriability conditions share that trend. Being the pioneer not always delivers good outcomes. Indeed, sometimes the company has arrived too early for the party, with an immature technology, and its followers would learn from its mistakes.

Winter concludes that what matters for appropriability is the ability to develop further innovations at modest incremental cost, therefore, implicitly paying attention to the natural trajectories and path dependency. The subtle internal dynamism of the successful R&D organization, a crucial competence, is harder to imitate than specific products. Therefore, not only the firms are dissimilar regarding strategies, structures, and competences, but they mainly made a substantial effort to maintain and amplify these differences, since these factors are crucial to be successful on the creative destruction game.

4. Science, innovation, and economic development

The relationships between science, innovation, and economic development were part of R. Nelson's concerns since the beginning of his professional activities in late 1950s and early 1960s. His first articles on the issue, "The simple economics of basic scientific research" (1959) and "The link between science and invention: The case of the transistor" (1962), were developed from his research at the Rand Corporation, which explains the empirical bias of his early works.

Nelson (2006), when summarizing these initial studies, highlights that his first insights were related to the perception of the dominant economic theory fragility in explaining the nature of R&D projects and technological change promoted by companies. This perception was also gaining momentum with contributions from other authors, such as C. Freeman, then in charge of the Science Policy Research Unit, at the University of Sussex (England).

Concerning the corporate R&D projects, Nelson stresses the strong connections between science and technology, emphasizing the need to consider "the complex institutional structures involved in R&D." Along this path, Nelson moved away from the

view that the institutions behind R&D, such as universities and research institutes, responded to "market failures" in the innovative process. Instead, he points out the collective, cumulative, and evolutionary character of technological progress.

> *"On the one hand, there were economists who viewed the processes and institutions involved as basically market ones but with many public programs and non-market institutions, like universities, involved in the system because of 'market failure'. On the other hand, there was a growing group of scholars who were coming to believe that one had to recognize the range of institutions, non-market as well as market, engaged in R&D right from the start of the analysis and that to view the non-market elements as a response to 'market failures' was an asymmetric and distorting interpretation of what was going on" (NELSON, 2006, p. 905).*

The author explored the complexity behind the relationship between science and technology in several works throughout his academic career, leading to diverse research themes. For instance, one focuses on the discussion of the connection between basic and applied research (Eisenberg; Nelson, 2003); another on the role of universities and public research centers in supporting the catching up processes along different sectors and countries (MAZZOLENI, NELSON, 2007; MALERBA, NELSON, 2011); and others on the issue of patenting (NELSON, 2006) and the importance of differences between the sciences (NELSON, 2016).

By identifying the complex institutional structure that underlies the relations between science and technology, Nelson initiates studies that generated the approach of "innovation systems" (NELSON, 1993). This theoretical approach, which was and continues to be widely disseminated in the academic world, presented an important set of developments related to both national and sectoral systems (MALERBA, 1992; MALERBA, NELSON, 2011) and places of innovation[1]. Furthermore, recognizing systemic features linked to the technological change has anchored public policies aimed at stimulating innovation in developed and developing countries in the last three decades.

Within the discussion of innovation systems, identifying the institutional support apparatus for companies and its role in stimulating innovative activities led Nelson to delve deeper into studies on the relationship between institutions and economic development, which permeates a large part of his works in the last two decades. In the article entitled "Institutions and economic growth: Sharpening the research agenda," Nelson declared that:

[1] Research on local innovation systems encompasses a set of recent studies from different fields of knowledge besides economics, such as geography and sociology. An important part of these studies is directly inspired by the innovation systems approach of evolutionary theory. For a summary of this discussion, see Asheim and Gertler (2006).

> *"The development of a solid understanding of how institutions affect economic productivity and progressiveness obviously is a very challenging task. The basic reason is that the relationships are not simple. The going will be especially hard if economists do not develop a coherent and broadly agreed-upon way of thinking about what institutions are, and how they affect economic activity that illuminates the complexities as well as the broad regularities. My central purpose in this essay has been to sketch out a perspective on institutions and economic change that does that." (NELSON, 2007, p.323).*

Nelson captured the complexity behind the institutional apparatus around innovative business activities by developing the concept of "social technologies." Regarding this discussion, he recovers the various dimensions in which the term "institutions" is utilized in the economic literature, from the idea of institutions as "rules of the game," which anchor economic activities, to their identification with physical structures. Based on this discussion, the author proposes that the term institution should be defined as *"…the factors and the forces that mold and hold in place social technologies"* (NELSON, 2008, p. 2). In the well-known phrase, "the devil is in the details," he summarizes the difficulties of identifying and suggesting the "right institutions" to promote technical progress and economic development.

Nelson (2008) discusses the aspects around the argument that social technologies develop more erratically and slowly when compared with physical ones. Whereas the scientific knowledge contributes much more robustly to elucidate the trajectories of technological development, the behavioral and social theories are more fragile in explaining how institutions work and what should be done to improve their functioning. There is a set of political, economic, social, and cultural elements that influence institutional creation and development that are difficult to grasp and reproduce in other contexts.

The social technologies that support or complement physical technologies are, therefore, more difficult to be constructed:

> *"…the vast field of social technologies, their intertwining with physical technologies, and the fact (or my argument) that they develop much more erratically and slowly than do physical technologies, provides a very attractive agenda for scholars of technological advance. Pursuing it will enable us to expand our horizons and get a much more complete hold on the processes that drive economic progress" (NELSON, 2008, p. 10).*

Therefore, the crucial role of institutions is to foster externalities and conform patterns of innovative activities by constructing investment incentive structures, workforce training, among others (NELSON, SAMPAT, 2001). Discussions of how to build an institutional framework for economic development are at the heart of an important work by the author in which he discusses how economic development processes were historically

shaped by an intertwining between market and non-market institutions (CIMOLI et al., 2007). In other words, constructing the institutional apparatus to support innovations (the "institutional engineering") has nurtured the creation of technological capabilities in organizations via different forms of learning. For executing this task, non-market institutions and public policies are essential (development banks, specialized agencies, training centers, class associations, etc.).

In this discussion, Nelson focused on the catching up processes from developing countries. Mazzoleni and Nelson (2007) analyze a set of successful cases in agriculture and industry, with special emphasis on the role of research centers and universities in creating conditions for autonomous technological development. One of the highlighted elements is how, in these investigated cases, the institutions did not act as "ivory towers". On the contrary, they were oriented towards technological solutions to specific problems faced by certain sectors[2].

When analyzing the catching-up process of some countries in specific sectors (telecommunications, software, pharmaceuticals, automobiles, semiconductors, and agro-food), Malerba and Nelson (2011) discuss the interconnections between national and sectoral innovation systems. More specifically, the authors scrutinize how some countries have been successful in developing certain business (agribusiness in Brazil, automobile and semiconductor industry in Korea, and pharmaceuticals and software in India), but failed in others (telecommunication equipment in India and pharmaceutical industry in Brazil).

Concerning the analysis of the regularities and differences around the cases of success and failure in catching up, Malerba and Nelson (2011) highlight:

(i) firms as key actors, and their differences in terms of size, previous capabilities, and origin of capital. Catching up processes in specific sectors may or may not require the participation of large companies, and foreign enterprises. Regarding these firms, different cooperative arrangements are possible to promote technological change (joint ventures, technology transfer agreements, etc.);

(ii) the different interactions with the other agents of the national innovation systems, such as universities, development banks, public agencies, among others, forming different types of networks;

(iii) the different knowledge bases of the sectors, which may be more related to major academy inventions, to internal R&D at firms, or even to processes of technological or organizational modernization;

[2] Among the cases analyzed by Mazzoleni and Nelson (2007), two are Brazilian examples: a) the development of soy production in the Brazilian cerrado (similar to the *savannah)*, which involved institutions such as the Instituto Agronômico de Campinas and Embrapa; b) the development of the Brazilian aeronautical industry, from the creation of the Centro Tecnológico da Aeronáutica and of the Instituto Tecnológico da Aeronáutica.

(iv) the institutions, of a national or sectoral nature, that shape the behavior of economic agents (laws, rules standards, norms, routines, common habits, established practices, among others);

(v) the public programs and policies implicitly or explicitly dedicated to technological change.

Their conclusions can be summarized as follows:

> *"In sum, the discussion in this article emphasizes the dynamic interplay between national – and sectoral – system variables in explaining why some sectors emerge and catch up and other sectors do not: national systems and institutional frameworks positively affect the development and growth of those sectors whose dimensions correspond and fit the national ones. Sectoral actors or institutions that prove effective in a specific sectoral system may be replicated or adopted with success in another sector if those sectoral systems have similar features. If basic features of the national systems or of the successful industries do not fit characteristics of a given sector, any attempt to replicate the actors or institutions in that sector may be useless for encouraging catch up. The dynamic interplay between national features and sectoral features is one of the most interesting areas of future research in the innovation systems literature" (MALERBA, NELSON, 2011, p. 1671).*

The differences between sectors, in terms of actors, knowledge bases and institutional frameworks, together with the analysis of the complex relationships between science and technology, have anchored a set of studies developed by Nelson in the field of health sciences (NELSON et al., 2011; MORLACCHI, NELSON, 2011; CONSOLI et al., 2016). Despite the different objectives and methodologies, these works highlight the complexity, interdisciplinarity, and diversity of agents involved in innovative activities in the area of human health, to identify how the so-called "health innovation systems" are constituted and how they evolved. Studies in this field of knowledge emphasize the interaction between basic research in different fields (biology, physics, pharmacology, etc.), where universities and research centers have a prominent role; applied research, in which R&D by companies is of paramount importance; and medical practice, with emphasis on the role of hospitals and healthcare professionals in the testing phases of new products for human use[3].

Considering a broader point of view, aiming to explain the long-term economic development, Nelson (2015) presents an analysis of the main weaknesses and gaps of the neoclassical theories of economic growth, especially the notion of equilibrium and the non-

[3] The literature that discusses health innovation systems has grown significantly in recent years and has proved to be of crucial importance for understanding the effects of the recent health crisis (the COVID-19 pandemic). The perspective of evolutionary theory has supported recent works such as those by Sampat and Shadlen (2021) and Callegari and Feder (2022).

consideration of non-markets institutions' role for technical progress. In this article, he also discusses certain weaknesses of the Schumpeterian approach (such as not considering the role of universities in technological change) and calls for the need for an integration between the neo-Schumpeterian and post-Keynesian approaches, which more effectively contemplates the role of demand in economic development processes (in contrast to the emphasis given to the role of supply by the new theories of economic growth, which the author criticizes in this essay).

In propositional terms, Nelson summarizes his point of view on the nature of economic development processes:

> *"My proposal is that there are at least three aspects of economic development that are important to understand, and each has been studied within a different framework: evolutionary analysis of innovation driven economic dynamics involving the rise and fall of different technologies firms and industries, study of the processes and actors involved in the creation and development of new technologies, and analysis of the institutions supporting technological advance and economic development. To understand development as we have experienced it we need to look at all three, and fit them together." (NELSON, 2015, p. 27)*

This paragraph arguably recapitulates many of Nelson's concerns throughout his long and fruitful academic career.

5. Consolidation of evolutionary theory: the publication of the book "Modern Evolutionary"

In 2018, after 36 years of publication of the important milestone for the consolidation of evolutionary theory, NW joined six other renowned authors for a new book, whose objective is to debate and systematize the advances and challenges of evolutionary economics in the economic debate. Unlike the seminal book of 1982, this new one brings discussions with a lower degree of mathematical formality, aiming to reach a wider audience, including from other areas of science, besides the economics.

Nelson opened with the first chapter presenting the evolutionary theory and establishing comparisons with the theoretical construction proposed by neoclassical economics. He highlighted the significant distinctions between the two approaches, with the debate on competition deserving emphasis for stating that it does not refer only to prices, but above all to innovation and its diffusion process.

> *"Evolutionary economists would argue that analysis of what goes on in the economy at any time cannot be separated from, but must involve in an integral way, explicit recognition of the dynamic processes involved in ongoing innovation-driven economic change. The core assumptions of neoclassical theory make it very difficult to do this" (NELSON, 2018, p. 4).*

Following the book, Nelson, alongside Dosi, revisited the main guiding concepts from the perspective of evolutionary economics, such as trajectories and technological paradigms, and point out some of their advances. Note that, for this chapter, Dosi developed a more formal analysis in the chapter's appendix.

Then, the discussion focused on the behavior of firms and how to build their capabilities. As discussed in the first section of this review-article, in 1982, NW presented an in-depth investigation of the companies' conduct, which is recovered at this point in the book, by scrutinizing the concepts of routines and "dynamic capabilities".

> *"Given that organizational capabilities consist of routines, many of the characteristics of capabilities derive from the characteristics of routines. Within firms, routines and capabilities rest often on firm specific communication codes that enable the exchange of information and coordination" (HELFAT, 2018, p. 91).*

To deepen the arguments already shown on the construction of evolutionary theory until 2018, Pyka and Nelson (2018) investigated the general elements about industrial dynamics and the way this economic activity evolves. The conclusions that stand out about the advancement of evolutionary theory can be summarized as follows:

> *"The point we are making here is that the orientation of evolutionary economics is at once roomy, capable of taking aboard a wide range of phenomena identified by empirical research as associated with the subject matter being studied, and theoretically broadly constructive, capable of making sense of how those phenomena relate and how they influence or are influenced by the evolutionary processes that generate them. Put another way, an evolutionary theory certainly does focus attention ex-ante on certain phenomena and processes, but is quite open to recognizing that a wide range of factors and mechanisms may be operative, and thus has the capability for developing a theoretical understanding of what is going on that is broadly responsive to what has been learned empirically" (PYKA; NELSON, 2018, p.127)*

Since it is always an aspect of the evolutionary economics approach, some chapters of the book developed an in-depth understanding of economic growth theories, including the debate on how the evolutionary process can enable catch-up movements for backward countries, highlighting the cases of countries such as South Korea and Taiwan.

Finally, in the seventh chapter, Dopfer and Nelson (2018) showed the outstanding elements in the evolution of evolutionary economics and point out aspects that need to be

developed in research agendas based on this theoretical framework. The first feature the authors highlighted, as already indicated in Nelson (2015), is the requirement for further investigations on the demand side, that is, "…an evolutionary perspective on household purchases of goods and services is needed," since he believes that the evolutionary theory has advanced much more in understanding of the supply side.

A second critical point concerns the need to advance investigations into the specifics of generating innovations in the service sector, given its growing importance for the current economies. This proposition is based on the diagnosis that evolutionary theory has focused its research on the manufacturing industry and that current knowledge about the different sectors is very uneven.

Another perspective for future investigations within the scope of evolutionary theory concerns the need to advance in understanding the growing levels of economic inequality that characterize advanced capitalist economies, focusing on the features of labor markets and the growing gap between the remuneration obtained by less qualified workers and those that belong to the managerial team. More specifically, Dopfer and Nelson propose that evolutionary theory should advance around the following issues: *"Why do the pressures to keep expenditures low on low or medium skilled workers outside of management seem to be much greater? How do these differences relate to the way firms are financed, and the beliefs and policies of people in the financial sector?"* (2019, p. 218).

Finally, while acknowledging recent advances, especially in attempts to articulate Schumpeterian evolutionary theory with the contributions of Keynes and post-Keynesians, Dopfer and Nelson argue that *"…we still are some distance from a persuasive evolutionary macroeconomics*" (2018, p. 220).

Final comments

In the introductory chapter to "The Oxford Handbook of Innovation", Fagerberg (2006) highlights the growth of literature on innovation from the 1960s in the field of social sciences. Indeed, it experienced greater strength since 1990s, as various academic institutions and specialized journal were developed, helping the growing knowledge on this issue.

As discussed throughout this review-article, the pioneering work of NW was key for understanding the systemic character of innovation and its own relevance for analyzing the evolution of economic systems. Some concepts, such as routine, search, and selection, have been fundamental for constructing a theory of the firm based on the Schumpeterian vision of "creative destruction".

Other developments in NW's work, such as national, sectoral, and local innovation systems, are also at the root of the deepening of knowledge about what innovation is.

Furthermore, understanding how: a) the innovation generation process takes place; b) it differs according to the sectors of economic activity; c) it influences the countries' economic growth and catching up processes, is very useful.

NW was extremely critical to the neoclassical theory in particular due to its disregard for the innovation process and for the differences among companies (strategies, structures, and dynamic capabilities, at least). By highlighting, modernizing, and deepening the Schumpeterian approach, NW turned the economic theory more realist and valuable. In the classic article of 1997, the authors were "in search of useful theory of innovation." Definitely, they achieved this goal.

References

ASHEIM, B.; GERTLER, M. The geography of innovation: regional innovation systems. **The Oxford Handbook of Innovation**, Oxford: Oxford University Press, 2006.

CALLEGARI, B.; FEDER, C. The long-term economic effects of pandemics: toward an evolutionary approach. **Industrial and Corporate Change**, v. 31, pp. 715–735, 2022. DOI: https://doi.org/10.1093/icc/dtab064

CIMOLI, M.; DOSI, G.; NELSON, R.; STIGLITZ, J. Instituições e políticas moldando o desenvolvimento industrial: uma nota introdutória. **Revista Brasileira de Inovação**, 6 (1), pp. 55-85, 2007. DOI: https://doi.org/10.20396/rbi.v6i1.8648941

COHEN, W; NELSON, R; WALSH, J. "Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent (or not)". Cambridge, MA: National Bureau of Economic Research, **NBER Working Paper,** 7552, 2000.

CONSOLI, D., MINA, A., NELSON, R., RAMLOGAN, R. **Medical innovation: Science, technology and pratice.** Oxon and New York: Routledge, 2016.

DOPFER, K., NELSON, R. The evolution of evolutionary economics. In: NELSON, R.; DOSI, G.; HELFAT, C.; PYKA, A.; WINTER, S.; SAVIOTTI, P; LEE, K.; MALERBA, F.; DOPFER, K. **Modern evolutionary economics**: an overview. New York and Cambridge: Cambridge University Press, 2018.

DOSI, G. Technological paradigms and technological trajectories. **Research Policy**, v. 11, pp. 147-162, 1982. DOI: https://doi.org/10.1016/0048-7333(82)90016-6

EISENBERG R. S.; NELSON, R. Public vs. proprietary science: A fruitful tension? **Academic Medicine**, v. 77, n. 12, pp. 1392-1399, 2003.

FAGERBERG, J. Innovation: a guide to the literature. In: FAGERBERG, J., MOWERY, D.C.; NELSON, R. **The Oxford Handbook of Innovation**. Oxford: Oxford University Press, 2006.

LEVIN, R.; KLEVORICK, A.; NELSON, R.; WINTER, S. Appropriating the returns to industrial R and D. **Brookings Papers on Economic Activity**, v. 18, n. 3, pp. 783-820, 1987.

MALERBA, F. Sectoral systems of innovation and production. **Research Policy**. V. 31, n. 247–264, 2002. DOI: https://doi.org/10.1016/S0048-7333(01)00139-1

MALERBA, F., NELSON, R. Learning and catching up in different sectoral systems: Evidence from six industries. **Industrial and Corporate Change**, v. 20, n. 6, pp. 1645-1675, 2011. DOI: https://doi.org/10.1093/icc/dtr062

MAZZOLENI, R.; NELSON, R. Public research institutions and economic catch-up. **Research Policy**, v. 36, pp. 1512-1528, 2007. DOI: https://doi.org/10.1016/j.respol.2007.06.007

MORLACCHI, P.; NELSON, R. How medical practice evolves: Learning to treat failing hearts with an implantable device. **Research Policy**, v. 40, pp. 511-525, 2011. DOI: https://doi.org/10.1016/j.respol.2011.01.001

NELSON, R. The simple economics of basic scientific research. **Journal of Political Economy**, v. 67, pp. 297–306, 1959.

NELSON, R. The link between science and invention, the case of the transistor. In: NELSON, R. (ed.) **The Rate and Direction of Inventive Activity**, Princeton University Press, 1962.

NELSON, R.; WINTER, S. In Search of Useful Theory of Innovation. **Research Policy**, v.5, p.36-76, 1977. DOI: https://doi.org/10.1016/0048-7333(77)90029-4

NELSON, R.; WINTER, S. **An evolutionary theory of economic change**. Harvard University Press, 1982.

NELSON, R. Why do firms differ and how does it matter? **Strategic Management Journal**, v. 12, Special Issue Winter, pp. 61-74, 1991.

NELSON, R. (ed.) **National Innovation Systems**. Oxford University Press: Oxford, 1993.

NELSON, R. *An agenda for formal growth theory*. Laxenburg: International Institute for Applied Systems Analysis (Working Paper, 94-85), 1994.

NELSON, R. The growth of patenting and licensing by U.S. universities: An assessment of the effects of the Bayh-Dole Act of 1980. **Research Policy**, v. 30, pp. 99-119, 2001. DOI: https://doi.org/10.1016/S0048-7333(99)00100-6

NELSON, R., SAMPAT, B. Making sense of institutions as a factor shaping economic performance. **Journal of Economic Behavior and Organization**, v. 44, pp. 31–54, 2001. DOI: https://doi.org/10.1016/S0167-2681(00)00152-9

NELSON, R. The simple economics of basic scientific research. ***Industrial and Corporate Change***, v. 15, n, 6, pp. 903-917, 2006. DOI: https://doi.org/10.1093/icc/dtl022

NELSON, R. Institutions and economic growth: Sharpening the research agenda. **Journal of Economic Issues**, v. 41, n. 2, pp. 313-323, 2007. DOI: https://doi.org/10.1080/00213624.2007.11507018

NELSON, R. Why do firms differ and how does it matter? A revisitation. **Seoul Journal of Economics**, v. 21, n. 4, pp. 607-619, 2008.

NELSON, R. What enables rapid economic progress: What are the needed institutions? **Research Policy**, v. 37, 1-11, 2008. DOI: https://doi.org/10.1016/j.respol.2007.10.008

NELSON, R., BUTERBAUGH, K., PERL, M., GELIJNS, A. How medical know-how progresses. **Research Policy**, v. 40, pp. 1339–1344, 2011. DOI: https://doi.org/10.1016/j.respol.2011.06.014

NELSON, R. Understanding long run economic development as an evolutionary process. **Econ Polit**, v. 32, pp. 11–29, 2015. DOI: https://doi.org/10.1007/s40888-015-0007-x

NELSON, R. The sciences are different and the differences matter. **Research Policy**, v. 45, pp. 1692-1701, 2016. DOI: https://doi.org/10.1016/j.respol.2015.05.014

NELSON, R.; DOSI, G.; HELFAT, C.; PYKA, A.; WINTER, S.; SAVIOTTI, P; LEE, K.; MALERBA, F.; DOPFER, K. **Modern evolutionary economics**: an overview. Cambridge, United Kingdom; New York, NY: Cambridge University Press, 2018.

PENROSE, E. **The theory of the growth of the firm.** Oxford: Oxford University Press, 2004.

SAMPAT, B. N., SHADLEN, K. C. The COVID-19 innovation system. **Health Affairs**, v. 40, pp. 400–9, 2021. DOI: https://doi.org/10.1377/hlthaff.2020.02097

SCHUMPETER, J. A. **Capitalismo, socialismo e democracia**. Rio de Janeiro: Zahar Editores, 1984.

TEECE, D.; PISANO, G. The dynamic capabilities of firms: An introduction. **Industrial and Corporate Change**, v. 3, n. 3, pp. 537-556, 1994. DOI: https://doi.org/10.1093/icc/3.3.537-a

WINTER, S. G. Appropriating the gains of innovation. In: DAY, G.S.; SCHOEMAKER, P.J.H. (org). **Wharton on managing emerging technologies**. New York, John Wiley & Sons, pp. 242-265, 2000.