CHAPTER 9

The Crisis of the Neoclassical Framework and the Schumpeterian Echo in the Current Paradigm of the Economic Analysis of Technological Change

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9.1 Introduction

When raising the need to review the attention that economic analysis has paid to issues related to innovation and technological change, it is necessary to address it with a double objective; on the one hand, the degree of exogeneity that has been attributed to the consideration of technological change (especially in the neoclassical approach), which would avoid the need to explain it from the economic model and would justify its merely tangential consideration; and on the other, to present how the

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consideration of this variable has evolved in terms of effects on the competitiveness of companies, productive sectors and economic systems, as well as on the potential for growth and economic development of countries and regions.

This reflection must start with Adam Smith, both because of the consensus that considers him the father of economic science, and because of Marx's vision that it is after the industrial revolution that the conscious application of knowledge on a large scale to productive activity occurs, thus generating important changes in economic activity and in the growth rates of the territories. In the words of Motta and Moreno (2020), classical economists were the first to consider the economic impact of technological change, with increases in productivity being the main effect and the division of labour being the facilitating element. This economist vision of technological change associated with gains in productivity and/or generation of new products forms the central axis of the works of Rosenberg (1982, 1994) and Stoneman (1983), the latter especially concerned with the process and the effects of the diffusion or generalization of technological change to the economy.

Despite being a matter dealt with from Classical Economics, economic thought relegated the analysis of technological change's exogenous element to the system in determining the supply functions, either from the micro or macroeconomic perspective. It was not until the second half of the twentieth century that Solow (1956, 1957) and Abramovitz (1956) "stumbled" upon the impact of technological change while estimating the sources of growth and found that more than half of the measured growth was due to different elements from the accumulation of capital and the human factor, that economic analysis turned once again to technological change, the element ("residue") to which this unexplained growth was attributed.

After this introduction, the rest of the work will be dedicated to analysing the four main paths from which economic analysis has approached the study of technological change (Antonelli, 2008). In Sect. 9.2, the approach based on the classical legacies of Adam Smith and Karl Marx will be addressed, focusing on the analysis of the determinants of the size of the "residue" and its regional and national differences, giving an important role to knowledge and its accumulation in capital goods, as well as the main criticisms of the neoclassical model. Section 9.3 refers to the approach based on the Schumpeterian legacy, which highlights the role of competitive processes, which condition the creation of knowledge, technology and innovations and determine the possibilities of growth and income redistribution. Section 9.4 focuses the attention on the evolutionary models and the systemic approach to innovation and knowledge (evolutionary approach and biological suggestions based on the Marshallian legacy in terms of Antonelli (2008). Finally, in Sect. 9.5, some reflections on cultural elements, creativity and innovation, which fit within what Antonelli (2008) called the Arrowian legacy are presented, since it pays special attention to the role of knowledge. We finish with the conclusions section, which to a large extent will highlight the existence of a kind of "cross fertilization" in the most recent approaches.

9.2 The Early Analysis of Innovation in Classical Economics and the Path to the Criticism of the Neoclassical Growth Theory

9.2.1 The Early Analysis of Innovation in Classical Economics

The radical changes brought to society during the Industrial Revolution and the birth of Political Economy as a discipline in the last third of the eighteenth century implied not only the transfer of resources and population from the activities in agriculture to industry but also radical changes related to the concepts of production, distribution and factors of production itself. It is in this aspect where another of the fundamental changes for the interpretation of production growth will take place, when the impact of innovation, which was already established as a catalyst for improving productivity in agricultural activities throughout the British agrarian transition, also leaked into the economic analysis of the Classical School.

Adam Smith in his *Wealth of Nations*, by highlighting the importance of philosophers or men of speculation, was incipiently recognizing the importance of what today we would call R&D activities, while pointing out the effects of mechanization on specialization and the division of labour in terms of productivity gains and the flow of constant improvements, finding in Book I a discussion of what today is identified as the sources and consequences of technical advance (Nelson & Winter, 1982). In this way, he would identify the two central elements to consider technical progress as an economic activity: (1) it is carried out to obtain advantage; (2) requires prior mobilization/investment of resources.

For Thomas Malthus and David Ricardo, although it is true that both are interested in the impact of technical change, this is interpreted as an exogenous factor and indirectly through the substitutability between machinery and the work factor that derives from technological improvement. Along these same lines, Ricardo ([1817] 2001; *On Machinery*) analysed the effects of the incorporation of capital goods (mechanization) on growth and income distribution, raised the possibility of asymmetric effects derived from the introduction of machinery in the production process, its orientation towards saving scarce production factors and the potential conflict between labour and capital (machinery), in what today we could call technological unemployment. John Stuart Mill, following Ricardo's thesis relative to the tendency of the economies to the stationary state, would incorporate the technical change in his analysis, but in this case, as a source of temporary disturbance of the path of growth.

It will be necessary to wait until Karl Marx and "Capital" to find an interpretation of technical progress as continuous and evolving, which returns to the essence of Smith's approach. For Marx, the progressive mechanization of production is a fundamental tendency of the system to achieve improvements in labour productivity, necessary for the self-expansion of the system (Shaikh, 1978), being explained by the pressure of competition in the market and not by private ownership of production and capital (Elster, 1992). This was a novel and fact to the activity that emerged from the industrial revolution, the conscious application of science to productive activities as a mechanism to respond to problems and needs of said activity (Rosenberg, 1974, 1976). As a result, the division of labour is constantly affected in a process of constant evolution and adaptation to the evolution of mechanization requirements, which makes technological change, its cyclical components and its effects on unemployment (industrial reserve army) in a component of the cumulative, evolutionary and dynamic process of development of the forces of production (Neffa, 2000; Ricoy, 2003).

However, the immediately subsequent evolution of economic thought relegated the analysis of technological change to an element exogenous to the economic system, in the determination of supply functions, either from the micro or macroeconomic perspective. It was not until the second half of the twentieth century that Solow (1956) and Abramovitz (1956) "stumbled" upon the residual when estimating the sources of growth and found that more than half of the measured growth was due to different elements. After the accumulation of capital and the human factor, economic analysis turned to look again at technological change, the element ("residue") to which this unexplained growth was attributed.

From then on, this approach focused on issues such as introducing technological change into an aggregate production function, how to measure capital and its different components more efficiently, and even refining the Solow and Abramovitz result to reduce the weight of the "residual," by expanding the range of explanatory variables, such as human capital (Mankiw et al., 1992). In any case, in a review of growth estimates for different countries and periods, by including the effects of human capital and R&D capital, Kyriakou (2002) finds that the "residual" effect of technological change was above 35%, with differences associated with geographical and temporal elements and with between 10% and 15% resulting from investment in R&D. From Kaldor's (1957) approach, a Technical Progress Function would have to be estimated, which would help to explain the relationship between the growth rates of per capita production and per capita capital, which implies the existence of two sources of economic growth: capital accumulation and technological progress, although there are limits to the capacity for capital accumulation and therefore to the rate of technical progress and the possibilities of economic growth.

The "Cambridge Controversies" initiated an intense debate over the foundations of Economic Growth Theory by confronting the capital theory of the economists attached to the neoclassical-Keynesian synthesis with its critics (Cohen & Harcourt, 2003) in a discussion focused on endogeneity problems to measure capital, the implications of using a dynamic or static framework and the heterogeneous or homogeneous nature of capital. Nevertheless, the criticism to the neoclassical growth paradigm will keep being central for decades until a new wave of criticism was elevated, its usefulness started to fade decades later due to its inadequacy to explain the lack of convergence for the modern economy

9.2.2 Criticisms During the "Cambridge Controversies"

The criticisms that unleash the debate by Joan Robinson are oriented towards the social implications of the relationships between the components of the economic mechanisms in the accumulation process, highlighting the fact that the productivity of capital and the efficiency of investment only have sense when they impact the objective living conditions of the population. In other words, the interest is not only in the "technical" part of the economic categories but also in their social counterparts.

In her 1953 paper, Joan Robinson connected the measurement problems of neoclassical capital theory with the methodological problem underlying the conception of dynamic analysis as a series of static equilibrium. The problem of endogeneity derives from the very dual nature of capital, as reflected in Pasinetti and Scazzieri (1990, p. 144):

> "Capital" can be conceived of in two fundamentally different ways: (i) … as a "free" fund of resources, which can be switched from one use to another, without any significant difficulty: this is what may be called the "financial" conception of capital; (ii) … as a set of productive factors that are embodied in the production process as it is carried out in a particular productive establischment: this is what can be called the "technical" conception of capital.

The generalization in the use of the financial conception of capital would thus provoke scenarios of "reswitching" of capital techniques and "reverse capital deepening" due to Wicksell effects,[1] both phenomena undermining the static equilibrium framework.

In Lazzarini (2011, pp. 39–52) "reswitching" will appear as the possibility that a production technique initially considered more capital-intensive, chosen for a given interest rate, is in turn also chosen for another range of interest rates. This would break the monotonous relationship between interest rates and factor intensity in production techniques. The "reverse capital deepening" would represent the possibility of a direct relationship between interest rates and the demand for capital, based on the heterogeneity of capital goods,[2] the central element of Lazzarini's analysis. These inconsistencies in the neoclassical theory of capital would lay the foundations for the criticism of Garegnani (1970) coming to question the validity of the marginalist theory to explain income distribution.

[1] In Joan Robinson (1953), we can find the exposition of Wicksell effects divided in Price Wicksell Effects, defined as changes in relative prices corresponding to a change in income distribution (with fixed technology); and Real Wicksell Effects, as changes in relative prices corresponding to a change in income distribution also with technical changes.

[2] This idea was early presented by Hayek in Investment that raises the demand for capital (1937), under the assumption that each kind of the heterogeneous capital goods present their own interest rates.

9.2.3 Criticisms Over Convergence

In his review of the empirical studies on convergence, De Long (1988) would open the door to various factors that would explain the lack of convergence in the levels of well-being of the different economies, especially since 1870. Among these factors, the most notable are the characteristics of the political system, cultural factors such as religion and, finally, the technological assimilation capacity of countries. This last factor would facilitate the inclusion of knowledge and technology in the theoretical framework of growth theory.

Mankiw et al. (1992) suggest the usefulness of studying the accumulation of knowledge as an element that would make it possible to close the unexplained gap of the exogenous technological component of growth. According to these authors, although it is true that the relationship between the savings rate and population growth proposed by the Solow model (1956) makes it possible to predict the trend of economic growth, the magnitudes of said growth could not be adequately predicted. These findings, together with those of Barro and Sala-i-Martin (1992), will lead to the development of the concept of "conditional convergence," emphasizing that the neoclassical model of growth "did not imply that all countries would reach the same level of income growth per capita income. Instead, what it implies is that countries would reach their respective steady states. Therefore, when looking for convergence in a cross-country study, it is necessary to control for differences in the steady states of different countries" (Islam, 1995, p. 1131).

9.3 Economic Growth Driven by Innovation and Technological Change

Faced with the neoclassical model based on comparative statics, the Schumpeterian conception of the economy is dynamic, and innovation plays a central role in the economic process and in the generation of growth, and the distribution of income. From this perspective, any point of equilibrium that might appear would be unstable and dynamic; being this instability and dynamism determined by innovation. In this sense, the Schumpeterian approach is a critique of the neoclassical orthodox vision based on equilibrium and comparative statics.

It is necessary to highlight the relevance of innovation and its endogenous character (at least when talking about the process of "creative accumulation," although the initial approach was exogenous in the process of "creative destruction") to the economic system, the result of the performance of the entrepreneur, the crucial agent, who can detect the opportunities associated with an invention or a new application of existing knowledge before others. In this sense, recognizing the important distinction between invention and innovation is paramount, inventions being a kind of "raw material" for the innovative entrepreneur, and the dependence on institutional elements, especially market structures. This distinction is in line with the vision of Rae (1834), for whom the generation of wealth depends on the emergence of new investment opportunities (reinvestment and capital accumulation) derived from the invention; note the similarity to the role of the Schumpeterian innovative entrepreneur in identifying and materializing such (re)investment opportunities. In other words, for Rae (1834), innovation is the key element in economic development, while capital accumulation is a consequence and not a cause of innovation; also note the similarity between this idea and the evolution of the model of creative destruction to that of creative accumulation in the Schumpeterian vision.

However, as Rosenberg (1976) highlighted, two crucial elements were left out of the Schumpeterian analysis: on the one hand, the limitations on the supply of knowledge (inventions), which generally operates as a restriction of technological supply in society in which employers must play their role; on the other, the important continuous and incremental nature of innovation as opposed to the vision of discontinuous innovation, both in the process of creative destruction and in that of creative accumulation. In other words, Schumpeter does not consider those minor innovations that do not immediately generate new products or productive sectors, but that do generate an accumulation of innovation and absorption capacity on the part of the companies and that will be decisive for a better future performance of the system of innovation (Freeman, 1974, 1982).

Heertje (2006, pp. 75–112) proposes to analyse the Schumpeterian model of innovation in terms of a disruption with respect to the stationary state. This analysis starts from a situation of stagnation, in terms of productivity and business benefits. At this point the Schumpeterian entrepreneur comes into play "discovering" a new way of combining technology and the resources at his disposal, thus generating profits and economic growth.

This phase of creative explosion is characterized by a first comer's type structure, so that innovation would generate initial benefits, diluting these as innovation spills over to other companies and industry. Once the initial momentum was lost, stagnation would return.

Thus, the innovation model could be identified with the technological gap model proposed by Posner (1961) and later developed by Hufbauer (1966), in which competitive advantages in international trade are due to a time lag in the innovation process, between the different countries. So the country that innovates first enjoys a privileged position in trade until its new technology trickles down to other countries.

Vernon (1979) analyses it in terms of the company's economy when considering its product life cycle. Also starting from an advantage based on the technological difference, Vernon disaggregates the growth phase into birth, maturity and standardization. Distinguishing these by the growth rate of profits and sales, and the relative importance of production factors.

It is vitally important to understand how Schumpeter focuses the innovation process, and therefore growth, on the offer, thus distancing himself from the idea that new products and processes arise from a previously unidentified demand.

9.3.1 Schumpeter: From Exogenous to Endogenous Innovation

When studying the concept of innovation in Schumpeter's work, some precision is needed because, throughout his life, this concept will be modified to such an extent that we can speak of two different models, model I exposed in *The Theory of Economic Development* (Schumpeter, 1912); and model II presented in *Capitalism, Socialism and Democracy* (Schumpeter, 1942).

Model I, represented in Fig. 9.1, starts from a conception of innovation exogenous to companies and existing market structures (that is for the whole system). In such conditions, a select group of entrepreneurs[3] capable of appreciating the potential of these exogenous innovations assume the risk of incorporating them into production. Thus, the market's mechanisms would come into operation, so that those entrepreneurs succeeding in incorporating innovations would generate a situation of temporary monopoly based on technology and thus will obtain extraordinary benefits.

The dynamics of this model I has certain similarities with Marxist interpretation of innovation. Since, for Marx, an innovation would mean a

[3] Who would play the entrepreneur's role in its full sense.

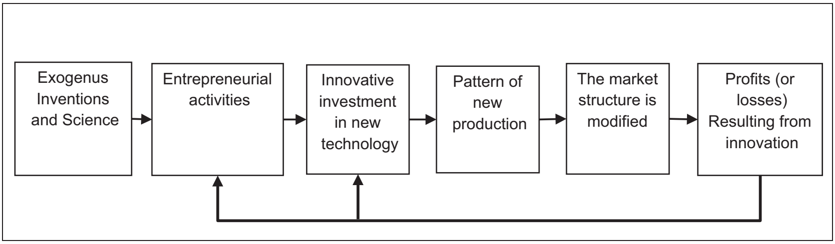

Fig. 9.1 Schematic representation of Schumpeter's Model I. (Source: Palma Martos, 1989, p. 101)

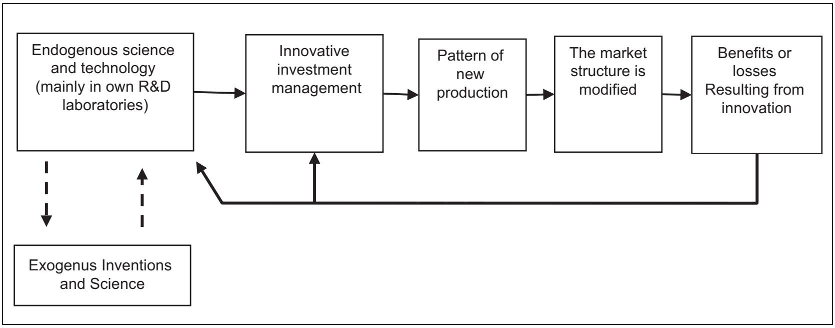

Fig. 9.2 Schematic representation of Schumpeter's model II. (Source: Palma Martos, 1989, p. 103)

temporary deviation from the stationary state, for Schumpeter it would represent a deviation, also temporary, in the market structure from perfect competition to monopoly.

Three decades later, the model II (summarized in Fig. 9.2) would incorporate the technology as an endogenous element of production. This change, in appearance contradictory in Schumpeter's vision, can be easily attributed to the author's own experience regarding the role of large companies in the innovative process. Since the birth of large companies as a differentiated economic actor during the last decades of the nineteenth century, the business class began to internalize the need to innovate as a growth engine. In this way, just as the Second Industrial Revolution and the new forms of work organization brought about the creation of human resources departments in companies, the need for innovation prompted the creation of R&D departments.

As shown in Fig. 9.2, it will be the companies' R&D departments that can give applicability to the scientific–technical discoveries that are produced exogenously. The dynamics of the process once these innovations are incorporated will not be very different from that presented in model I, although now the temporary monopoly arising from the innovation may tend to be extended over time given the positive feedback occurring between the results of the successful innovations and increased investments in R&D. The essential difference between Schumpeter's models I and II lies in the incorporation of endogenous scientific and technical activities carried out by large companies.

9.3.2 Schmookler and the Demand-Induced Innovation

Faced with the Schumpeterian vision of innovation as a process mainly arising from supply, Jakob Schmookler was the great promoter of the demand-pull hypothesis. In this approach, consumers, through changes in their demand functions, would generate a market signal about the products that could best satisfy their needs. The entrepreneurs would initially take a reactive role since the initial effects of the motivation behind a change in demand are, however, not specific. Schmookler's approach is summarized in Fig. 9.3.

However, only those entrepreneurs capable of correctly identifying these changes as a demand for specific goods that best meet consumers' needs will reap extraordinary benefits. Thus, Schmookler would suggest that *demand tends to generate its own supply* (Schmookler, 1965).

This vision certainly has suggestive elements about the role of demand through the market as an attraction mechanism for business decisions. As can be seen in Fig. 9.3, the success different companies face to the new demand will be determined by competition between their production techniques. Schmookler would identify the incentive for the search and application of an invention in a competitive industry through two elements: (1) the correlation between the elasticity of demand and alternative supply in the absence of innovation; and (2) the volume of demand. Furthermore, he opens the door to a specific analysis of research and development activities as a differential branch of business behaviour, a function that would later be included in the development of the Theory of Endogenous Growth.

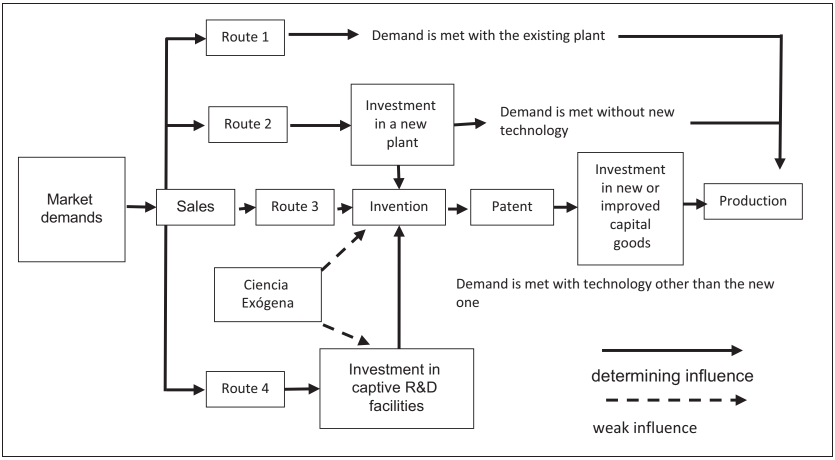

Fig. 9.3 A schematic summary of Schmookler's model. (Source: Palma Martos, 1989, p. 98)

9.4 Growth, Technology and Innovation in the Current Approach

In the process of "cross fertilization" developed through the coexistence and debate between the different approaches, we can point out that the main characteristics of the current approach (those prevailing after debate) are related with the systemic approach of innovation and with the endogenous consideration of the generation of knowledge and its application to innovation. Thus, one of the effects of the diffusion of technological change (Stoneman, 1983) to the innovation system (Freeman, 1974, 1982, 1995) as a whole would be improvements in productivity that would translate into economic growth above the expected from factors accumulation. Thus, an endogenous character to growth arises, allowing more refined estimates of growth components or determinants, including the effect of the accumulation of human capital (Romer, 1994; Sala-i-Martin et al., 2004) and R&D capital (Kyriakou, 2002; Romer, 1994); nevertheless, the main share of growth is explained by innovation and technological change, and investment in R&D, even discounting the effect of the accumulation of human capital and capital in R&D (Kyriakou, 2002). However, from the distinction based on the radical or incremental nature of innovation or technological advances (Freeman & Pérez, 1988), the growth associated with productivity can be understood as a result of incremental changes (whose cumulative effect is captured by estimates of the effects of technical progress in the long term), while radicals can also generate a reconfiguration of the economic system, which is not differentially identified by such estimates.

Considering that innovation has a systemic nature, which may differ across countries and regions, means moving away from the orthodox neoclassical approach to deep into the heterodox analysis of historicism (both the German and British schools) and institutionalism (Archibugi & Michie, 1998; Lundvall, 1992). Additionally, understanding that there is an important endogenous component in the generation of knowledge, innovation and growth, means moving away from orthodox neoclassical growth models à la Solow (Solow, 1956, 1967, 1994), which maintain the exogenous vision of technological change, analysed on an aggregate scale, and address growth as a phenomenon of discontinuous change between equilibrium, in which the role of innovation and technological change is to explain the ("residual") part of growth, estimated from the aggregate production function, that cannot be explained by the change in the accumulation of capital and labour factors. Thus we are moving from an exogenous consideration of innovation and technological change to an endogenous perception, already pointed out by Schumpeter (1942) when he defined the model of creative accumulation in what it has come to be called (Freeman et al., 1982) the Type 2 model, to differentiate it from creative destruction (Type 1 model).This endogenous approach allows us to address issues abandoned by neoclassical analysis, including the effects of competitive rivalry and market structures, the complexity of technological change and its disruptive and destabilizing effects, the complex interactions between sources and factors of growth, and the role played by institutions in the performance of economic activities (Nelson, 1997). Furthermore, it provides answers to the criticisms made to the logical consistency of neoclassical models, discussed above when addressing the so-called *Cambridge Controversy*.

9.4.1 The Theory of Endogenous Growth and Knowledge Generation

The New Theory of Growth or Theory of Endogenous Growth emerged last century in the late 1980s and the early 1990s, to respond to the limitations of the Neoclassical Growth theory. That research were focused on to incorporate into neoclassical models mechanisms to overcome the limitations pointed out by heterodox approaches, especially to incorporate technological change as an endogenous element to the economic process (Aghion & Howitt, 1990; Grossman & Helpman, 1991; Romer, 1990). Thus, the economic literature referring to these models as "endogenous growth models." In general, these models respond to the criticisms pointed out by Nelson (1997) regarding the partial appropriability of technological knowledge, the incentive effects derived from non-competitive market structures, the positive returns of R&D expenses and the Side effects on old technologies (obsolescence and loss of competitiveness of technologies, companies, sectors and economies). However, they do not address issues related to innovation trajectories and uncertainty in that process (Nelson, 1997).

Cortright (2001) characterizes the Endogenous Growth Theory by two main elements: (a) his vision of technological progress as an indirect effect of economic activity; and (b) the existence of increasing returns in knowledge and technology that drive the growth process. This view of the role of technology and knowledge is rupturist with Solow's (1956, 1967) neoclassical growth model, where the potential growth of an economy was determined by the saving rate or the per capita stock of capital; leaving technology as an exogenous variable to explain the divergence of the growth rate between countries with similar savings rates. But it also supposes a break with the vision initially pointed out by Adam Smith, for whom technological change was the result of the division of labour in the process of firms seeking for individual benefit, which through the phenomenon of accumulation and reinvestment of capital constituted the key factor in the increase in productivity observed during the Industrial Revolution (Smith, 1776, p. 112).

The new interpretation of the implications from the human capital framework was consolidated around two "types" of the endogenous growth models, based on whether the accumulation process of human capital is driven by a process of learning by doing or by direct investment in the "creation of new knowledge."

- *Learning models.* In Romer (1986, 1990, 1994) can be found a production function AK with spillovers of knowledge in production. The model can be written as: $Y = AK^{\alpha}L^{1-\alpha}\kappa^{\eta}$; where κ are the spill-over effects of capital investment; and η measures the sensitivity of the economy to these spill-over effects.

Lucas (1988) presents a similar model, but in this case, it is the per capita capital ratio of the economy that would be the origin of the spillovers of knowledge in the economy, instead of being the level of the stock of capital.

- *Increases in the stock of knowledge*. The key idea behind this generation of endogenous growth models lies in defining a growth path for knowledge and technological level, in analogy with the accumulation of physical capital. Romer (1990) presents a model of three sectors where labour is distributed between the production of technological knowledge and the production of consumer goods; differentiating the production of the R&D sector as a production factor additional to the classical production factors.

  Benhabib and Perli (1994) present a variant of the Lucas-Uzawa model under the same premise of knowledge accumulation, but understanding human capital as a complementary factor to the labour factor, which increases its productivity; and focused on the time invested to increase human capital.

9.4.2 Nelson and Winter: The Evolutionary Approach to Innovation

When we jointly consider the systemic nature of innovation and the endogeneity of technological change, going beyond endogenous growth models is needed. The relationships between patterns of technological change and growth patterns must be addressed in the context of interactions between agents with different capacities for innovation and absorption–imitation. That is, by analysing the interrelationships and competition processes, essentially asymmetrical, between components of a markedly heterogeneous group. As response, Nelson and Winter (1982) propose an evolutionary approach in which companies make not only productive decisions, but also technological ones. Firms search for knowledge and existing production techniques, or they generate them within the company, and make decisions about technology incorporation based on expectations (subject to error and uncertainty) about the rate of return between different technologies. As a result, an evolutionary process of selection arises, both on production techniques and on companies, whose survival and pre-eminence (face both, to existing competitors as well as to potential incumbents) depend on the efficient selection of technology under conditions of uncertainty. It is this evolutionary character with a dynamic and stochastic component that gives this approach its name.

Among the advantages of evolutionary models, their ability to explain both time series and the microeconomic aspect of technical change stands out. In this sense, both the differences between companies and the imbalance in the system appear as essential aspects of economic growth commanded by technical change. The relevance or inertial effect of historical elements (path dependence) in the body of knowledge and practices constituting the existing technological and knowledge stock, as well as in the processes of mastery (knowledge capitalization) and progress (increase in the stock of knowledge) and its application to economic activity, become the critical factors of technological change and thus determinants to this evolutionary process (Nelson & Winter, 1982).

9.4.3 Freeman and the Systemic Approach of Innovation

Despite the important contribution, evolutionary models do not sufficiently address the issues inherent to the legal and institutional framework and the historical context in which evolutionary processes take place, under different conditions in different temporal and geographical contexts. The possibility (in terms of capacity and probability) of introducing an innovation in the market is mediated by many conditions that do not depend only on firms and that are closely related to the levels of development of the country or region in which they operate, establishing an indissoluble relationship between the micro and macro aspects in innovation processes (Natera, 2022): the availability of qualified workers (which in turn depends on the quality, extension and intensity of the educational system), access to the necessary inputs (linked to the degree of openness of the economy), administrative and bureaucratic limitations (related to the institutional maturity) and the existence of a sufficiently large market for products (which is related both to country's income levels and distribution of income and wealth, as well as to competitiveness and access to international markets).

This set of interactions, relationships and interdependencies generated a new approach (Edquist, 1997, 2001, 2004; Freeman, 1974, 1987, 1995, 2002; Lundvall, 1992; Nelson, 1993) that analysed the innovation process from a systemic and holistic perspective, structured by three key elements (Pérez, 1996; Soete et al., 2010): (1) the existence of agents, institutions and organizations, public and private, that interact with each other with different frequency and with different objectives (the system); (2) the identification, use, generation and dissemination of knowledge, its applications and technological and organizational (innovation) improvements; and (3) contextualization in a specific geographical (national, regional or local) area (subsequently extended to sectorial approach by Malerba, 2005, 2008), which also includes an evolutionary and dynamic component.

In this sense, the current concept of Innovation System, referring both to geographical or sectoral approaches, is the result of a complex process of "cross fertilization" between contributions, whose origin is usually established in the ideas of List (1841) on the existence of a National System of Political Economy (Lundvall, 1992; Erbes & Suárez, 2020, Suárez & Erbes, 2021), in which there are also elements of the historical schools (German and British), the institutionalism, the Marxist vision of the relationship between technological change and economic systems, the Marshallian perception of the institutional context as a determining factor of economic activity, the Schumpeterian analysis of the innovative process as a determinant of economic development, and the crucial role of interactions in the process of creating and diffusing knowledge and technology, giving rise to a prolix approach in literature in which Freeman, Lundvall, Nelson and Edquist occupy a central place.[4]

When addressing the relationship between National Innovation Systems and development, we must be aware that, although the approach was not born as a theory of development, it offers tools to understand both, development processes (impacts of economic growth on the standard of living of the society to which the system refers) and the differences between systems (countries, regions, or sectors) and its determinants. Compared with the aforementioned limitations of the orthodox approaches to growth (whether exogenous or endogenous), the systemic approach has the advantage of considering the role of capacities (technological or innovative, absorptive, and social) and other dimensions, such as market structures and institutions, to understand development as an improvement in the level and living conditions of society in the Myrdalian sense (Johnson

[4] For an interesting and recent synthesis of the process of generating the concept of Innovation System and the development of the powerful methodological tool it provides for economic analysis and policy design, including a differential analysis from the perspectives of central economies and peripheral countries (especially those in Latin America), see Erbes and Suárez (2020).

et al., 2003). At the same time, this entails considering innovation as a multidimensional problem and context dependent, so that different dominant drivers of innovation may coexist according to different contexts (Hong et al., 2012).

When considering technological capabilities, the systemic approach to innovation refers to three elements (innovative, absorptive and social capacities), that complement and interact with each other and with the other components of the system as market structures, institutions, and other non-market elements (Lall, 1992). Thus, technological and *innovative capacities* refer to the potential of companies (Bell & Pavitt, 1995; Patel & Pavitt, 1997) and of countries (Archibugi et al., 2009; Castellacci, 2011; Fagerberg & Verspagen, 2007) or sectors (Malerba, 2005, 2008) to generate new knowledge or new applications of existing knowledge, which are transformed into innovations and technological change; *Absorptive capacities* are associated with the potential to incorporate to the production process innovations, knowledge and their applications, even if they have been generated outside the system; *Social capacities* have to do with cultural factors, the social consideration of entrepreneurs and innovators, risk aversion, entrepreneurial spirit, etc. (Kim, 1997; Lall, 1992). In other words, every country, region or sector will evolve following a certain trajectory as a consequence of the combination and interaction of economic, technological and sociopolitical aspects that will generate different patterns of innovation and development profiles (Castellacci & Natera, 2016; Natera, 2016; Dutrénit et al., 2019, 2011).

The generation of capacities is closely related to the patterns and volumes of investment in human and physical capital and the technological and innovative effort, and can be understood as the capacity of firms (micro) and of the whole set of economic agents (macro) to develop an effective use of knowledge (scientific, technological and of general purpose) for its application in the productive process and transform it into innovations, in a process in which investment strategies play an important role (Bell & Pavitt, 1995; Lall, 1992; Patel & Pavitt, 1997).

Jointly with this potential, the systemic approach has certain limitations, mainly derived from the scarce attention paid to sociopolitical factors (power relations, trust in institutions and their efficiency…), generally addressed as a conditioning factor, sometimes even exogenous (Natera, 2022), but with a lower degree of importance than technoeconomic factors (Pérez, 1983). As a result, a limit arises in the capacity of systemic approach to analyse and formulate recommendations to enhance the so-called social capacities that determine the system adaptative capacity to changes in knowledge patterns and converge towards higher levels of development (Abramovitz, 1986), or to identify what type of institutions favour the functioning of the system of innovation and enhance the results of the other capacities (Cozzens & Sutz, 2014; Von Tunzelmann, 2003).

9.5 Conclusions

The importance and effects of technological change on the economic system, including its endogenous character, were early perceived by economists of the classical-Marxist approach. In general terms, they focused on their effects on productivity and labour specialization and the effects of capital accumulation.

However, in the marginalist-neoclassical approach, the attention paid to this topic was scarce and it was not reconsidered until the estimates on the determinants of growth in the mid-twentieth century found that two thirds could not be explained by growth factors and were attributed to a "residual" factor, which was identified with technological change.

The response inside the neoclassical approach focused on incorporating technological change as an (exogenous) source of growth, along with capital accumulation, and refining the elements of the aggregate growth function to include, among other variables, the accumulation of human capital and technological capital (R&D). The main controversy within this neoclassical approach was related to the distinction between financial capital and technical-productive capital and the incorporated nature of technology in the replacement of technical-productive capital and the effects of the interest rate on the choice of heterogeneous techniques with different capital intensity. Despite this, the residual component was still around 35% of growth.

Outside of the orthodox neoclassical approach, the Schumpeterian vision stood out in the first place, proposing a dynamic vision of the economy based on the central role of innovation and the entrepreneur. This supposes a supply side approach and a pioneering consideration of the endogenous nature of innovation and technological change (which constitutes an essential source of change and instability, generating dynamism) and moves away from neoclassical analysis based on comparative statics and the search for equilibrium. In this way it is possible to explain growth and competitiveness (both in micro and macroeconomic perspective) on the basis of innovation. This is compatible with the interpretation of the origin of competitive advantages as result of innovation, as well as with explaining growth and development differentials on as a consequence of technological gaps.

The current approach is the result of the interaction between different researches lines developed in the last decades of the twentieth century. Based on endogenous growth models, innovation and technical change were integrated into the functioning of economic activity highlighting their ability to generate increasing returns (due to improvements in knowledge and technology) that drive the process of growth. On the other hand, evolutionary models seek to take into account the existing relationships between growth patterns and technological change patterns, which are developed in a context of interactions between agents, with different capacities for innovation and absorption–imitation, who make both productive and technological decisions. To do this, they pay attention to the asymmetries in the interrelationships and processes in non-competitive market structures and to the heterogeneity of agents and institutions involved in the innovation process. From this perspective, a selection process is developed between productive techniques and between companies, whose survival and pre-eminence generates an evolutionary process, both in the firms' characteristics and in the predominant technologies.

The endogenous-evolutionary approach is complemented by the systemic approach, which allows addressing issues inherent to the legal and institutional framework, the context in which endogenous decisions are made, and the evolutionary processes that take place; thus, it is possible to address the relationship between micro and macro aspects in innovation processes. The systemic approach is structured around three essential elements: the system (agents, institutions and organizations, public and private, that interact with each other with different frequency and with different objectives), innovation (identification, use, generation and diffusion of knowledge, its applications and technological and organizational improvements) and the scope (geographic—national, regional or local—and/or sectorial contextualization), while also including an evolutionary and dynamic component. The differences between systems and their results (innovative, growth, competitive, or of any other nature) are largely explained on the basis of differences in terms of capacities (technological and innovative, absorptive and social).

In summary, the current focus in the economic analysis of innovation and technological change is the result of a complex conceptual and methodological "distillation" process, which considers innovation as endogenous to the economic system, which generate an evolutionary path in innovation and growth, having effects on the whole system. As a result, Innovation Systems constitute a powerful tool, with theoretical robustness, to explain differential dynamics in development paths identify the determinants of these differences, promote the benchmarked practices and strategies of existing system and design policies to correct inefficiencies or weakness when detected.

However, certain limitations arise, mainly derived from lower attention paid to sociopolitical factors (power relations, trust in institutions and their efficiency…), generally considered as an exogenous conditioning factor, while the main attention is paid to techno–economic factors. Therefore, there remains significant room for improvement via reinforcing attention to sociopolitical aspects, so that the systemic approach gains the capacity to analyse and make recommendations to enhance the so-called "social capacities" or to identify which institutions promote the functioning of the innovation system and enhance the results of the other capacities.

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