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The Growth Conundrum: Paul Romer's Endogenous Growth

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Abstract

The explanation and causes of economic growth, the problem of convergence of per capita income among different economies, the low productivity growth in many advanced economies, and the presence of disrupting technological innovations remain at the center of the debate among economists. The present contribution analyzes the endogenous growth theory of Paul Romer and discusses its features and content through Romer's main works on the topic. This study on Romer's work highlights the existence and importance of increasing returns in the process of growth, the key role of knowledge, the ideas as non-rival goods, the existence of externalities, the endogeneity of technological change, and the primary role of human capital, especially in research activity. Institutions, such as property rights are important as well. The state also has a decisive role in education and the research sector. Another relevant aspect is that economic growth and technological change are closely interconnected; they cannot be separated. Romer's theory of endogenous technological change ties the development of new ideas and economic growth to the number of people working in the knowledge sector. New ideas, being non-rival and partially excludable, are fundamental for growth since they make everyone producing physical goods and services more productive. Finally, Romer's endogenous growth highlights the factors that provide incentives for knowledge creation; thus, his theory can also be considered a significant contribution to the theory of the knowledge-based economy.

Keywords: endogenous growth, technical change, human capital, knowledge accumulation, externalities, property rights

JEL Classification: O30, O40, D62, J24, I20

1. Introduction

A general but important question economists ask is why countries all over the world, characterized by poorly developed economies in the recent and distant past, show a great capacity for growth, becoming in some cases true leaders. Another issue is whether per-capita income across different countries is converging. A further challenging question is why advanced economies, in particular, no longer seem able to grow at an average annual rate of at least 2%, as in fact, it has occurred for about three decades since the seventies.

Today, modern industrial economies are increasingly characterized by rapid changes in technological knowledge and disruptive innovations. In addition, the increasing interdependence between economies reinforced by globalization processes, the emergence of the fourth industrial revolution, and the role of human capital and its learning capacity are undoubtedly important factors in influencing growth. These processes profoundly transform the economies, subjecting them to structural changes where some regions, sectors, and companies grow more compared to others, in terms of productivity and competitiveness. Another aspect of growth is that, despite the acceleration of technological progress, productivity growth has slowed for about twenty years. Thus, in the end, the issue of growth looks like a conundrum.

This paper is a contribution to the discussion about growth theory, highlighting the key role of knowledge, technical change and innovation, human capital and learning, and institutions, but without any claim to solve the conundrum that surrounds the theme of growth. In particular, the paper presents and discusses Paul Romer's endogenous growth.

Romer is one of the pioneers of the endogenous growth theory. In his theoretical view, the accumulation of knowledge is at the heart of long-term economic growth, and ideas, being non-rival, drive growth in the market. Therefore, Romer's analysis demonstrates how new ideas can drive sustainable, long-term economic growth.

The second section briefly explains the methodology followed in this contribution. The third section examines Romer's endogenous theory, followed by a section focusing on his models developed in a competitive market structure with externalities and based on the development of new knowledge. The fifth section analyzes the fundamental model of Romer's endogenous theory that stresses the role of ideas and their non-rivalry feature, the relevance of the research sector and human capital, and the presence of monopolistic competition. Romer and the convergence debate is the topic of the sixth section. The final section discusses Romer's endogenous growth and presents conclusions.

2. Methodology

This paper represents a theoretical analysis of Romer's contribution on endogenous growth. It is a discussion about his growth theory and the main factors that determine economic growth. Our analysis and discussion remain at the conceptual and theoretical level. The study is based on the literature material provided by Romer on the topic of endogenous growth, but other important papers of economists related to Romer's growth theory are examined. Although theoretical developments on growth theory have been accompanied by a growing number of empirical studies, this contribution does not provide an empirical analysis or any test of hypothesis concerning Romer's theory, or more generally the so-called *new growth theory*. However, we examine the empirical literature concerning Romer's endogenous growth and the discussion on the issue of economic convergence and divergence, characterizing the debate between the neoclassical and the endogenous growth theory.

3. Endogenous Growth Theory and the Relevance of Romer's Contribution.

The neoclassical growth theory has had as its reference point the growth model of Solow (1956). The main hypotheses of Solow's model are the presence of decreasing marginal returns, an exogenous rate of increase in technical progress, the convergence between economies with the same initial conditions, a long-term growth rate of zero. Different savings rates explain differences in income levels across countries (Schilirò, 2017).

From the 1980s onwards, a new growth theory that endogenizes technological change has been developed. The basic point of this endogenous growth theory is the importance of the role of increasing returns. Actually, Allyn Young (1928) already stressed the importance of increasing returns in economic progress. Thus, for this reason, he can be considered the forerunner of the modern theory of endogenous growth. Later, Nicholas Kaldor, Young's pupil, in his model of growth (Kaldor, 1957) indicates the existence of increasing returns to scale and inserts them into his *technical progress function*. So, increasing returns entered into the debate of growth theory.

Then, a very large group of economists worked on this topic at a theoretical level, such as Romer (1986a, 1990), Lucas (1988), Grossman and Helpman (1991, 1994), Weitzman (1998). (Note 1) While on the empirical side the literature became quite huge (e.g., Barro, 1991; Alwyn Young, 1991; Barro & Sala-i-Martin, 1992; Hall & Jones, 1999; Temple, 1999; Easterly & Levine, 2001; Mankiw, Romer, & Weil, 1992; Quah, 1993; Sala-i-Martin, 2002) and favored by the availability of new data on cross-country performance, mainly discussing the problem of convergence. (Note 2) Other empirical studies such as Helpman and Krugman (1985), Grossman and Helpman (1989, 1990), and Rivera-Batiz and Romer (1991) analyzed the connection between international trade and economic growth. A general consideration from the analysis of empirical literature on growth theory is that findings are contradictory and far from conclusive.

Paul Romer is certainly the leading scholar of the new growth theory that aims to endogenize technological change. In fact, Romer's research led to the modern understanding of economic growth. For his contribution, he was awarded the Nobel Prize in 2018. A key aspect of Romer's contribution was to rejuvenate the theory of growth and relaunch the importance of economic growth at a time when macroeconomics was mainly studying inflation and unemployment (Jones, 2019).

Romer develops models of growth that are essentially based on hypotheses that somehow endogenize technological change. This theoretical choice is founded on empirical evidence, since such models seem to explain growth data better than traditional growth models based on diminishing returns that show falling rates of growth. Romer (1986a) admires the aggregate long-term growth models developed by Ramsey (1928), Cass (1965), and Koopmans (1965) for their simplicity and rigor. (Note 3) This is why he aims to provide an empirically relevant model with increasing returns that possesses these features.

Thus, Romer starts focusing on questions such as "What are the determinants of long-run rate of economic growth in living standards?" A first answer to this question is given in Romer's article (1986a), "Increasing returns and long-run growth," where he emphasizes the ability to generate endogenous growth through new knowledge. Romer (1986a) like Lucas (1988) demonstrate that the long-run rate of growth can be directly explained by agents' decisions, without resorting to some exogenous technological progress. In his view, the new knowledge develops within the economic system and have positive effects in terms of productivity and growth of the product per capita. A qualifying aspect of his theory is that new knowledge is assumed to be an intangible capital good and fundamental input of production that has increasing marginal productivity.

Romer recognizes that there were early attempts to develop a model where increasing returns are the results of specialization, but the loose treatment of specialization undermined these attempts. Romer, however, returned to the topic of specialization in "Growth based on increasing returns due to specialization" (Romer, 1987). In this contribution, Romer brings out an already pre-existing idea in economic thought that the explanation of economic growth should be attributed to increasing returns generated by the division of labor. In fact, Romer (1987) provides a growth model where increasing returns arise because of specialization. This model is based on a multiplicity of intermediate goods, taken as representing the degree of specialization in an economy. Moreover, the model is characterized by expanding product varieties with long-run growth being stable. The rationale of using expanding sets of input is to mitigate diminishing returns.

4. Romer's Models on Increasing Returns, Competitive Equilibrium, Knowledge, and Externalities.

The original aspect of Romer's theoretical framework (Romer, 1986a) is that knowledge is a new basic form of capital and changes the formulation of the standard aggregate growth model. According to Romer (1986a, p.1004), the assumption of increasing rather than decreasing marginal productivity of the intangible capital good knowledge is the key to the reversal of the standards results about growth. His model represents an equilibrium model of endogenous technological change in which long-run growth is driven primarily by the accumulation of knowledge by forward-looking, profit-maximizing agents (Romer, 1986a, p.1003).

In Romer's view (1986a, p.1003), the production of consumption goods—as a function of the stock of knowledge and other inputs—exhibits increasing returns. In particular, the function of production is assumed to be globally convex when all other inputs are held constant. This function implies the existence of a maximum feasible rate of growth for per-capita output. This depends on the assumption concerning the research technology, that is, the diminishing returns in research will limit the rate of growth of the state variable. (Note 4) Also, in contrast to models in which capital exhibits diminishing marginal productivity, knowledge will grow without bound. At the same time, the diminishing returns in the production of knowledge are required to ensure that consumption and utility do not grow too fast. Furthermore, investment in knowledge involves a natural externality. In fact, "the creation of new knowledge by one firm is assumed to have a positive external effect on the production possibilities of other firms because knowledge cannot be perfectly patented or kept secret" (Romer, 1986a, p.1003). (Note 5) Thus, the presence of externalities is essential for the existence of equilibrium.

These three elements—externalities, increasing returns in the production of output, and decreasing returns in the production of new knowledge—combine to produce a well-specified competitive equilibrium model of growth. According to this competitive equilibrium model, the level of per capita output in different countries need not converge; growth may be persistently slower in less developed countries and may even fail to take place at all (Romer, 1986a, p.1003).

Romer (1986a) is aware that, due to externalities, the equilibrium growth rate of the economy may be lower than is optimal. In this regard, he states:

> Despite the presence of increasing returns, a competitive equilibrium with externalities will exist. This equilibrium is not Pareto optimal, but is the outcome of a well-behaved positive model and is capable of explaining historical growth in the absence of government intervention. (p. 1004)

Moreover, Romer recognizes the key role of learning. He identifies Arrow's model of "learning by doing" as an important starting point of dynamic growth models based on increasing returns. However, Romer's model departs from Arrow's by assuming that knowledge is a capital good with an increasing marginal product.

Before explaining his theoretical models, Romer analyzes the data of per capita GDP to support evidence in favor or against traditional models based on diminishing returns. Although Romer recognizes the difficulty in correctly measuring all the inputs to production, especially for intangible capital inputs such as knowledge, he states, "there is no basis in the data for excluding the possibility that aggregate production functions are best described as exhibiting increasing returns" (Romer, 1986a, p. 1013). Without a doubt, this contribution represents one of the first attempts to explain divergent growth patterns in different countries based on the accumulation of knowledge, also taking into account the spillover effects.

In Romer (1986a), there are two models. The first is a greatly simplified version of his increasing returns growth model. It is a discrete-time model of growth with two periods (1986a, pp. 1014–1018). The model represents a competitive equilibrium, which satisfies a constrained optimality criterion, in the absence of any governmental intervention. In this model, it is assumed that the production is a function of the state of knowledge (treated as a stock of disembodied knowledge) and a set of additional factors: physical capital, labor, and others. The production function exhibits increasing returns to scale, because the function is assumed to be homogenous of degree one and increasing in the aggregate stock of knowledge.

The second model is an infinite-horizon growth model. Romer analyzes the existence and characterization of a social optimum. His conclusion is that the social optimum cannot be supported as a competitive equilibrium in the absence of government intervention (Romer, 1986a, p.1023). Also, he discusses the existence and characterization of the competitive equilibrium, showing that the economy represented in the model has a suboptimal equilibrium in the absence of any government intervention, analogous to the equilibrium for the two-period model.

As in the two-period model, the production function is homogenous of degree one. Thus, it is assumed that factors other than knowledge, such as physical capital, labor, and the size of the population, are held constant. A key distinguished feature of this infinite-horizon growth model is that population growth is not necessary for unbounded growth in per capita income.

The rate of growth of knowledge is represented by

$$\dot{k} = G\,(I, k)^2 \tag{1}$$

Where I is the amount of forgone consumption in research, since additional knowledge can be produced by forgoing current consumption, and k is the current stock of private knowledge.

The function G is assumed concave and homogenous of degree one. Therefore, the accumulation equation, written in terms of proportional rates of growth, is

$$\dot{k}/k = g\,(I/k), \text{ with } g(y) = G\,(y, 1) \tag{2}$$

In this model, a crucial assumption is that g is bounded above by a constant, α. Such assumptions impose a strong form of diminishing returns in research. In fact, given the private stock of knowledge, the marginal product of additional investment in research, Dg, falls so rapidly that g is bounded. Romer specifies that $Dg\,(0) = 1$. This means that “one unit of knowledge is the amount that would be produced by investing one unit of consumption goods at an arbitrarily slow rate” (Romer, 1986a, p. 1019).

The assumption of increasing returns arises because of increasing marginal productivity of knowledge justifies the conjecture that, even with fixed population and fixed physical capital, “knowledge will never reach a level where its marginal product is so low that is no longer worth the trouble it takes to do research” (Romer, 1986a, p.1020). Romer also points out that knowledge has spillover effects that can be quite large. In addition, he stresses that the production of new knowledge exhibits some form of diminishing marginal productivity at any point in time.

This model presented by Romer is limited to a case that is the polar opposite of the usual model with an endogenous accumulation of physical capital and no accumulation of knowledge. However, the model here can be interpreted as a special case of the two-state variable model in which knowledge and capital are used in fixed proportions.

To conclude, this contribution (Romer, 1986a) has the merit of highlighting the increasing returns and underlining the importance of research and knowledge for growth, the existence of externalities, and not Pareto optimality of the equilibrium. However, a first limit of Romer (1986a) is, according to Romer (1994, p.14), that although the technology is provided as a side effect of private investments decisions, that is of entrepreneurial activity, technology is still treated as a pure public good, just as in the neoclassical model. A second limit is that the relation linking profit-driven private endeavors to technological progress was initiated but left somewhat unexplored. In fact, Romer assumes spillovers from private research that lead to improvement in the public stock of knowledge and, at the same time, keeps a price-taking competitive framework with no monopoly power that requires the assumption of a production function homogenous of degree one in all of its inputs, including the research and development activity, which is still treated as a rival good.

5. Endogenous Technological Change, Ideas, Non-Rivalry, Human Capital, Monopolistic Competition

In the article, “Endogenous technological change,” (1990) Romer provides his fundamental contribution to endogenous growth theory by developing a different model, where the mechanism of how the discovery of new ideas is at the basis of economic growth is explained. In fact, an idea is essentially the discovery of how to produce a new good. As underlined by Jones (2019), the key insight of Romer (1990) is that ideas are non-rival, therefore, they are different from nearly every other good.

Why is the non-rivalry of ideas important for economic growth? Simply because non-rivalry gives rise to increasing returns. In fact, using ideas (non-rival) and other inputs (rival) together in production, the result will be to get increasing returns, and these will generate growth.

In order to make a dynamic analysis, as in the previous models, Romer characterizes this new model with a single state variable. However, a new feature of this model concerns the introduction of market power, following Schumpeter (1942). (Note 6) In fact, Romer adopts a monopolistic competition market structure and its relative pricing system. In this analytical framework, firms sell the newly produced goods for a price higher than the costs of production, which are constant, applying a mark-up on costs. In this regard, Romer takes inspiration from the *variety models* by Dixit and Stiglitz (1977) and Ethier (1982; Jones, 2019). This allows him to describe firms and individuals that have market power and to justify that they earn monopoly rents on discoveries (Romer, 1994). In addition, this model emphasizes the importance of human capital in the research process.

The following premises are at the base of the model (Romer, 1990, p.S72): first, technological change lies at the heart of economic growth. Technological change provides the incentive for continued capital accumulation. Together technological change and capital accumulation account for much of the increase in output per worker. (Note 7) Second, technological change arises in large part because of intentional action taken by people who respond to market incentives. Thus, the model is one of endogenous rather than exogenous technological change. Third, technical knowledge is inherently different from other economic goods. This is a very fundamental premise. In this regard, Romer (1990) points out that:

> Once the cost of creating a new set of instructions has been incurred, the instructions can be used over and over again at no additional cost. Developing new and better instructions is equivalent to incurring a fixed cost. This property is taken to be the defining characteristic of technology. (p. S72)

According to Romer (1990), given these three premises, a purely competitive equilibrium with price-taking is not feasible. In his view, an unregulated economy is not no longer the best of all possible worlds; there is a role for institutions to play.

A key feature of Romer's monopolistic competition model is the recognition that ideas, while non-rival, are not pure public goods. Romer (1990) underlines that conventional economic goods are both rivalrous and excludable, privately provided, and traded in competitive markets. By treating ideas as non-rival goods, without being pure public goods, it is possible to talk about spillover effects, that is, incomplete excludability. In fact, excludability is mainly a function of the institutions, not a property of economic environment. Institutions like the patent system can allow ideas to be partially excludable, at least for a certain period (Jones, 2019). The two features of ideas—unbounded growth and incomplete appropriability—are generally recognized as being relevant for the theory of growth. Moreover, according to Romer (1990), these features are inextricably linked to non-convexities.

Thus, whereas in Romer (1986a) the production function is homogenous of degree one in all its inputs for the sake of simplicity also neglecting that research and development spending (i.e., the creation of new knowledge) is a non-rival good, in this new monopolistic competition model of endogenous growth, Romer treats the research activity as a non-rival, partially excludable good. In this model, externalities (increasing returns to scale) come from specific research and development sectors, which implies knowledge spillovers deriving exclusively from the activities of the research sectors. Romer's model draws the results from the static theory of trade with differentiated goods (e.g., Helpman & Krugman, 1985), that is, fixed costs lead gains from increases in the size of the market and, therefore, to gains from trade between different countries. However, the most interesting feature of the equilibrium showed by Romer is that increases in the size of the market affect not only the level of income and welfare but also the rate of growth. In Romer's model, larger markets induce more research and faster growth.

Another relevant feature that emerges from the analysis of the model is that the growth rate is increasing in the stock of human capital. However, it does not depend on the size of the labor force or population. Furthermore, the presence of a large domestic market is not a substitute for trade with the rest of the world. According to this theoretical view, in a limiting case that can be relevant for the poorest countries, if the stock of human capital is very low, growth may not take place at all.

Moreover, although Romer is sympathetic to the learning-by-doing formulation (Arrow, 1962; Lucas, 1988), he criticizes this formulation as unsatisfactory for several reasons (Romer, 1990, p. S77). One of these is that such formulation takes the strict proportionality between knowledge and physical capital or knowledge and education as an unexplained and exogenously given feature of the technology. Finally, since he adopts a single state variable in order to make a dynamic analysis, this model assumes that the excludable good (i.e., the benefits of research and development) that the firm produces intentionally is used in fixed proportions with physical capital. (Note 8)

A concise, non-formal description of the model is as follows. Romer presents a neoclassical growth model with technological change made endogenous. He identifies four basic inputs: capital measured in units of consumption goods, labor (*L*), human capital (*H*) as the rival component of knowledge, and (*A*) as the non-rival, technological component (Romer, 1990, p. S79). In particular, human capital is a distinct measure of the cumulative effect of activities, such as formal education and on-the-job training. Essentially, it takes into account changes in the quality of the labor force due to changes in observables, such as the level of education and experience. (Note 9) While *A is* an index of the level of the technology. *A* can grow without bound since its existence is separated from that of any individual. *H* can be devoted either to the final output (H_y) or to the research sector (H_A).

The model has three sectors. The research sectors use human capital and the existing stock of knowledge to produce new knowledge. An intermediate-goods sector uses the designs from the research sector together with forgone output to produce a large number of producer durables that are available for use in final-goods production at any time. A final goods sector produces the final output (Romer, 1990, p. S79).

Romer makes several simplifying assumptions. First, the population and the supply of labor are both constant. Second, the total stock of human capital in the population is fixed, and that fraction supplied to the market is fixed. Thus, the supply of the aggregate factors *L* and *H* is fixed. To simplify the dynamic analysis, the attention is restricted to equilibria with constant growth rates. Third, assuming that capital can be accumulated as forgone output is equivalent to assuming that capital goods are produced in a separated sector that has the same technology as the final output sector. Fourth, research is considered part of human capital, and "knowledge-intensive is translated into an extreme specification in which only knowledge and human capital are used to produce new designs or knowledge" (1990, p. S80).

The final output *Y* is a function of physical labor *L*, human capital devoted to final output H_y, and physical capital. There is the assumption determining an unusual feature of the production technology, which disaggregates capital into an infinite number of distinct types of producer durables (x_i). These types of capital goods are not all substitutes for each other, but some pairs are close substitutes, while other pairs are complements, and many others fall somewhere in between.

Romer (1990) points out that "there are many equivalent institutional arrangements that can support any given equilibrium" (p. S82). However, the equilibrium here is based on the assumption that anyone engaged in research has free access to the entire stock of knowledge. Furthermore, the model assumes linearity in *A* that results in unbounded growth. Therefore, "unbounded growth is more an assumption than a result of the model" (Romer, 1990, p. S84).

Regarding knowledge, a new design increases the total stock of knowledge and enables the production of a new good that can be used to produce output. However, what is important in terms of the results of the model is that knowledge is a non-rival good that is partially excludable and privately provided (Romer, 1990, p. S85).

Prices of the specialized durables are set through a monopoly pricing solution. The consumers are endowed with fixed quantities of labor *L* and human capital *H* that are supplied inelastically. Romer (1990, p. S88) points out that equilibrium in this model will consist of paths for prices and quantities satisfying several conditions. Among them, the supply of each good is equal to the demand; holders of human capital decide whether to work in the research sector or the manufacturing sector taking as given the stock of total knowledge *A*, the price of designs, and the wage rate in the manufacturing sector. Moreover, each firm that owns a design and manufactures a producer durable maximizes profits, taking as given the interest rate and the downward-sloping demand curve it faces, and setting (monopolistic) prices that maximize profits.

Romer (1990) recalls an important positive implication suggested by this model, "what is important for growth is integration not into an economy with a large number of people but rather into one with a large number of human capital" (p. S98). Thus, an economy with a larger stock of human capital will experience faster growth. This finding led Romer to argue that free international trade can act to speed up growth. Moreover, the model suggests why low levels of human capital can help to explain the weak or absent growth observed in underdeveloped economies.

In a subsequent article, Rivera-Batiz and Romer (1991) look at the importance of the increasing flows of ideas and the increasing returns of the research and development in relation to economic integration between similar advanced economies to foster long-run rate of economic growth. (Note 10) They underline that expanded international trade increases the number of specialized inputs, increasing growth rates. Thus, trade and the absence of barriers are elements that favor growth. According to Rivera-Batiz and Romer (1991, p. 550), integration will raise the long-run rate of growth purely because it increases the extent of the market.

Finally, a robust welfare conclusion of the model is the influence of the rate of interest on the rate of technological change. In addition, the best policy would be to implement direct subsidies that increase the incentive to undertake research. However, a second-best policy would be to subsidize the accumulation of total human capital (Romer, 1990, p. S99).

In conclusion, in Romer (1990), the importance of increasing returns of the research and development sector for the growth is highlighted. However, the fundamental relevance of Romer (1990) is the understanding of implications of non-rivalry related to ideas and its connection with increasing returns in relation to economic growth.

6. Romer and the Convergence Debate

The topic of convergence concerns whether per-capita income across different countries is converging. The convergence hypothesis supports the view that poorer economies' per-capita incomes will tend to grow at faster rates than richer economies. Convergence is one of the central arguments in Solow's model (1956). In particular, Solow predicts that there is a convergence between similar countries. Moreover, Solow (1957) applies his analytical framework of exogenous growth, based on decreasing returns, to US data. The results of the empirical analysis show that growth of capital and labor explains only a small part of actual growth, while the unexplained residual is very large.

However, Romer (1994) stresses that his main motivation to develop a new growth theory based on endogenous technological change (as in Romer, 1986a) is to show that classical economists (like Malthus and Ricardo) were wrong about prospects for growth. In fact, according to Romer, "Over time, growth rates have been increasing, not decreasing" (1994, p. 11).

Romer also entered the empirical debate of the convergence controversy (1986a, 1990, 1994). Particularly, Romer (1994) compares neoclassical models and their empirical applications versus endogenous growth models. The convergence controversy represents, in fact, one of the critical issues between the neoclassical growth and the endogenous growth theories. The first observation by Romer (1994) is that cross-country convergence is strongly dependent on two central assumptions of the neoclassical model: the exogeneity of technological change, the equal technological opportunities available in all countries of the world. Romer obviously rejects the first hypothesis on exogeneity by offering an endogenous explanation of technological change. However, through the analysis of the empirical literature that provides models not radically different from the neoclassical model (e.g., Barro & Sala-i-Martin, 1992), Romer (1994) points out that "convergence takes place, but at a very slow rate" (p. 8). (Note 11)

To Romer (1994), an important aspect of convergence is the diffusion of knowledge. In fact, the speed of convergence is determined primarily by the rate of diffusion of knowledge and is not essentially related to the exponents of capital and labor of the aggregate production function (Romer, 1994, p. 9). Moreover, the investment in human capital becomes a driver to economic convergence of different countries on long-term growth rates (Romer, 1990).

The central argument of Romer's analysis about convergence controversy is that convergence "captures only a part of what endogenous growth has been all about" (1994, p.). In his view, it is misleading to focus on data as the only scarce resource in economic analysis and to give too much weight to indicators such as t-statistics. Endogenous growth theory encompasses a much broader important story about growth and technological change. It can offer policymakers something more insightful than the standard neoclassical prescription, shedding light on discovery, diffusion, and technological change. In fact, it can give suggestions about market incentives and government policies such, for instance, tax subsidies for private research, the scope of protection for intellectual property rights, the links between private firms and universities, the mechanisms for selecting the research areas that receive public support (Romer, 1994, pp. 20–21).

In conclusion, endogenous growth theory can suggest the best institutional arrangements that help growth both in developing and developed countries through the best use of new knowledge.

7. Discussion and Conclusions

Romer’s endogenous growth theory aims at understanding the process of technological change and explaining the actual growth of the economies. The major contribution of Romer’s theory is that it has reinvigorated the investigation of the determinants of long-term growth (Pack, 1994; Jones, 2019).

Romer's theoretical contribution explicitly identifies technology as an input in the production function. However, technology has characteristics different from other factors of production, similar to physical objects. Essentially, Romer's growth theory deals with the interaction between the accumulation of greater knowledge and other more traditional inputs (1986a, 1990) or “objects” (1993).

An important feature of Romer’s theoretical contribution is that increasing returns are incorporated into his endogenous growth models. Another fundamental characteristic is the strategic role of human capital, as emerges, in particular, in Romer (1990) for its use in the research sector. Thus, Romer provides a theory of endogenous technological change that highlights the role of researchers and entrepreneurs.

A significant implication that emerges from Romer's works is that economic growth implies technological change, or that technological change accompanies growth. One cannot but have both. Growth driven by technological change involves that it is necessary to recombine things. New value is created by the new recombination and is fundamentally different. Therefore, there is a qualitative and quantitative transformation of the economy, its production processes, and its products.

Romer's endogenous growth theory is an attempt to use analytical tools to answer questions such as why growth and technology accelerate over time. A first explanation, inherent to the discovery process, concerns the role and characteristic of learning: the more you learn, the more you can learn, and the faster you can learn. Of course, this makes sense in the world of the discovery of ideas. This concept emerges clearly in Romer (1986a). Second, more importantly, it can become easier to discover things when others have learned. This second aspect implies the creation of better habits over time, a more effective way than in the past to exploit the opportunities for discovery.

Acemoglou, Johnson, and Robinson (2005) observe that Romer’s growth theory fails to consider the institutions to explain growth. However, in his analysis, Romer takes into consideration institutions such as the market, property rights, and the state. He uses the standard tools of economics, such as incentives and institutions, to understand what would affect the speed of technological change and influence the rate of growth of the economies. In this regard, Romer's theoretical analysis highlights the role of property rights and market exchange as the best practices that can be created to derive value from scarce physical goods. In fact, Romer believes that some nations have very low living standards compared to others because they have not implemented types of institutions such as the market economy with property rights. Particularly in Romer (1990), there is a significant result: the combination of monopoly power and spillovers—that is, intellectual property rights—as mechanisms for creating value. Regarding the role of the state, he thinks that there is room for state action within his vision of endogenous growth based on the creation of new knowledge and new ideas.

In Romer’s endogenous growth theory, there are also other institutions, the customs and applications of science, which nourish and support the economy and operate with different guidelines. In addition, although the institutions of the market and those of science are both important, there is the problem of how to use both, being aware that they follow sets of different habits. This is why policies have the task of defining the rules of the game in order to draw a line of separation, for example, between property rights and license rights on new ideas. Moreover, for most ideas, Romer maintains that it should be necessary to create weak and incomplete property rights so that it is possible to generate new entries and new competition. This would allow private-sector incentives to encourage the development of new ideas. However, this may not be sufficient.

Actually, the advanced economies, which are knowledge-based economies, are becoming more and more characterized by the fact that an increasingly large portion of the labor force is dedicated to solving problems, considering all possible ideas, while a relatively minor portion actually creates the products (Schilirò, 2012). Thus, the most appropriate institutional structure emerging from Romer’s theory is a structure of property rights over ideas and discoveries in the private sector but limited in the case of ideas; and also, subsidies to innovation from the state through the financing of people's education. The logic behind this institutional structure is that increasing the number of people dedicated to research moves the frontier of technological knowledge and possibly increasing the rate of growth. Thus, the key role of human capital, of its qualitative improvement through public and private investment in education, appears evident.

In conclusion, our analysis highlights how Romer emphasizes the importance of the role of creativity and technological development for the growth of an economy. In his theoretical view, knowledge creation and knowledge accumulation are key. Romer has not solved all the issues that determine the growth conundrum. However, he has given important and significant contribution helping to understand the growth process and its determinants. Finally, one concluding remark that we can draw from the above analysis is that Romer with his contributions to growth has also fueled the development of the economics of the knowledge economy.

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Notes

Note 1. For an account of the research on new or endogenous growth theory, Barro and Sala-i-Martin (2003).

Note 2. A survey and evaluation of the empirical contributions regarding endogenous growth is in Pack (1994) and Temple (1999). For a more recent survey of both theoretical and empirical works of New Growth Theories, Capolupo (2009).

Note 3. The original model was developed by Frank Ramsey (1928). Ramsey's was a planning problem (i.e. the allocation of resources chosen optimally by a planner that tries to maximize the utility of households). Later, David Cass (1965) and Tjalling Koopmans (1965) extended the model to a decentralized environment where households supply labor, hold capital and consume optimally, given prices and wages; while firms rent capital, hire labor to maximize profits, given prices and wages; and markets clear. In both approaches, there are no market imperfections, so the first welfare theorem holds: the competitive decentralized equilibrium is a solution to the planner problem.

Note 4. Romer (1986b) gives a general proof that restrictions on the rate of growth of the state variable are sufficient to prove the existence of an optimum for a continuous-time maximization problem with nonconvexities.

Note 5. Romer recognizes that knowledge has spillovers effects.

Note 6. Schumpeter emphasizes the importance of temporary monopoly power as a force that favors the process of innovation (Romer, 1994).

Note 7. Romer (1990, p. S72) acknowledges that his model resembles the Solow (1956) model with technological change. However, while Solow distinguished the factors of production in capital and labor, Romer distinguishes between ideas and everything else, that in Romer's language (Romer, 1993) are the "objects."

Note 8. Romer (1990, p. S77) points out that with this assumption, the model ends up having dynamics similar to those of Arrow's learning-by-doing model.

Note 9. Romer (1990, p. S79) specifies that it is a more limited concept of human capital than that used in theoretical models of growth; instead, it corresponds to the practice of growth accounting applications.

Note 10. In Rivera-Batiz and Romer (1991), this integration takes the form of trade in goods, flows of ideas, or both, depending on the form of the model.

Note 11. This result depends on the assumption regarding the absence of capital mobility.