Asian Development Policy Review
ISSN(e): 2313-8343
ISSN(p): 2518-2544
DOI: 10.18488/journal.107.2018.62.50.69
Vol. 6, No. 2, 50-69

URL: www.aessweb.com

REPRESENTATION OF THE HISTORY OF THE TECHNICAL PROGRESS IN THE LITERATURE ABOUT ECONOMIC GROWTH: A COMMENT

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Article History
Received: 22 February 2018
Revised: 22 March 2018
Accepted: 30 March 2018
Published: 2 April 2018

Keywords
Technical progress
Productivity growth
Economic growth
Schumpeterian theory
Neoclassical growth theory
Endogenous growth theory.

JEL Classification:
N0, O3, O4.

ABSTRACT

The aim of this paper is to analyse the history of the technological change, more specifically the technical progress, in related literature and its impact on the economic growth. A set of theories have been historically developed from the Schumpeterian theory till the new growth theories as the 1980's endogenous growth theory and the 1990's neo-Schumpeterian endogenous growth theory. Thanks to their ideas, these last theories have known growing interest among economists, exceeding, therefore, the Schumpeterian theory.

Contribution/ Originality: This study contributes in the existing literature in depicting the limits of the Schumpeterian theory, even though the latter is considered as the first theory of its kind and the most recognized concerning the role of technical progress in economic growth. The endogenous growth theory is an illustration of this.

1. INTRODUCTION

The production capacity of an economy depends on resources available and on the way they are used. Many economists have applied the concept of the 'production function' to shape the production capacity of an economy at a specific moment of time. Nevertheless, the economic functions are scarcely at the limit of this capacity. Indeed, an imperfect assignment of the resources, an under-use of production factors as well as a poor economic and social structure are likely the reasons why a given economy would never completely reach the full production capacity. The gap between the potential product and the real product of an economy depends therefore on the return of investment and the social organization. The border marking the realizable production depends itself on the technology available and on the control of the companies and the institutions of the concerned country.

The size of an economy grows as the quantity of inputs increases (laborers, machines, materials, energy,…). However, the population growth usually limits the labor's growth rate. Moreover, since the investment in fixed assets (machines, equipment of production, buildings,…) depends on saving, capital growth is restricted by the population's choice to consume later and save now. Consequently, if the transformation pattern of inputs to outputs does not change, concisely, if there is no technological progress, a stop of the economic growth in terms of gross domestic product (GDP) per capita will hence be witnessed; a halt at the limit set by demographic considerations and the desire of the population to save.

Therefore, a major part of better standard of living, measured by means of the GDP per capita, comes from the improvements of the productivity, which is considered as a link between outputs and inputs used in the production process, and which also measures the effectiveness of the economy. The most common indicator used remains the productivity of labor force, measured by the added value per hour worked or per employee. Nevertheless, it is only a partial measure of productivity because its importance and its evolution in time are based on other productive factors, particularly the amount of capital invested. Indeed, the output of labor increases as machinery and equipment replace the latter. Thus, there is a better measurement for productivity is what the economists call 'total factor productivity' (TFP). It is measured by the ratio between production index and the index made up of inputs used in production.

Given the fact that an economy almost never reaches the limits of its production capacity, observed variation in productivity is actually the result of a combination of return on investment changes and an expansion in production possibilities, that is to say it is the result of technological change. Indeed, the OECD (1992) reports that "the total factor productivity is a residual value of the economic growth which cannot be explained by an increase in basic inputs such as labor force and capital, and therefore must be attributed to technological progress".

Historically, economists, particularly those who have studied the technological change, have cumulated and analyzed a multiplicity of empirical evidences on aspects of the technological change, as well as the links between this change and the economic growth. That's why we will focus, in a first part, on the appreciative theories relating to empirical evidence which have analysed links connecting new technology to economic growth. Specifically, a special attention will be accorded to Schumpeter's theory considered as the pioneer and the most significant one dealing with the role of technological change as a determinant of economic growth. Then, interest will be brought to the other two parties on the different formal models of economic growth, respectively, the neoclassical growth model and the endogenous growth model, which constitute a theoretical basis for a more realistic illustration of interactions between various aspects of technical progress and economic growth.

2. THE SCHUMPETERIAN THEORY REVISITED

The economic change in the long run, called 'development', had been the favourite theme of Schumpeter. This economic development means a sustained increase of national incomes, which can be realized by the growth of profits at the firms' level. At this level, Schumpeter (1934) focused on a special field of economic analysis corresponding to a way to realize and improve profits. We are referring here to the newly created economic activity that generates new sources of productive effort. In this area, profits are the results of the creation of new productive fields. Thus, in this case, profit growth is not due to growth in the market power at a given point of time, but it is the result of a continuous process of activities creating new added value. More specifically, it is a process of constant changes and improvements. In this case, the firm is a mechanism for innovation, which consists in the introduction of new production processes, new products, new management methods, as well as new organization of production activities. It should finally be noted that this field represents the theory of profits through the innovation of Schumpeter.

Courvisanos (2009) mentioned that in the Schumpeterian theory, innovation is defined in five shapes: 1. New products unfamiliar to consumers; 2. New methods of production or new processes; 3. Opening up new markets; 4. New sources of raw materials and 5. New organisation of the competitive structure of an industry. This original theory of profits through innovation of Schumpeter (1934) considered profits as resulting from innovation which are heightened rather than maximized. Indeed, in contrast with the classical economists[2], capitalist reality does not support production maximization and thus profit maximization. In addition, this theory has focused on the role of entrepreneurship or the innovator entrepreneur. It is therefore speaking about entrepreneurial profits, while referring to the distinction between the invention or discovery on the one hand, and innovation, marketing and entrepreneurship on the other hand. Von Tunzelmann (1995) underlined the role of managerial firms in leading the innovation process. His analysis is based on Coase and Williamson surveys which argue that "managerial hierarchies are often cheaper ways of achieving certain incomes rather than relying on markets[3]".

After this earlier work on entrepreneurship, Schumpeter has become aware of the increased internal research and development (R&D) in large firms in the XXth century. Thus, the author conceived to enhance the interpretation of his original theory of profits through innovation (1934) via the role of large firms as key agents for innovation. At this level of thinking, the theory of profits through innovation by Schumpeter (1942) which was known under the name of 'Schumpeterian hypothesis', linked the profits based on the market power to innovation. Therefore, the market power became an important source of innovation. So, the 'Schumpeterian hypothesis' links the size of the firm, the market power and the innovation. Given this association between the market power and innovation through profits, Courvisanos (2009) focused on the political aspects of innovation by mentioning that these aspects do affect the competitive structure of a given market. If competition level is high under a given political environment, super-profits due to innovation will be dissipated rapidly.

Moreover, Courvisanos (2010) expanded his point of view, which is still based on Kalecki's political economy approach by mentioning the need to move to another wave of innovations which allow the clearly recognised unsustainable technology systems to be replaced by eco sustainable technologies. However, political environment still puts barriers to these types of innovation in different ways across the globe.

Innovation is the main source of technological progress. According to Schumpeter, technological change also called technical progress is defined as any change resulting from the application of information[4] to the production process (the application of information actually does not necessarily mean the use of new information. Indeed, the larger part of growth comes from the diffusion of existing information, not from new knowledge). This allows improving output, that is to say to produce new or improved products, with less resources. Thus, there will be a rise of total factor productivity.

Schumpeter's thesis remains valid with respect to the objective of each producer to preserve a maximum market power. Indeed, one can quote at this level the purpose of companies, working on activities closely related to technological innovation, to impose their products on the market, in an environment of a monopolistic competition. Thus, according to Schumpeter (1942) the pure and perfect competition (PPC), which is a condition of maximum economic efficiency, does not exist: "The introduction of new production methods and new goods is hardly conceivable if, at the outset, innovators must rely on the conditions of perfect competition". Thus, the only efficient model of competition is monopolistic. It constitutes a condition of economic efficiency within the capitalist economy. It is characterized by a fight on the ground of the novelty and quality. Consequently, according to Schumpeter, monopolistic positions are created through innovation. Once the monopolistic organization is established, prices of new products diffused on the market by innovative entrepreneurs will be formed, partially or completely, according

[2] The term 'classical economists' has been used to refer to the example of English economists who worked between 1776 and 1848. Smith, Ricardo, Malthus, Senior and Mill are prominent names.

[3] Von Tunzelmann (1995).

[4] Or knowledge or technology; any of the concepts is often used without distinction.

to the rules of monopolistic prices. By selling the new product at the monopolistic price, entrepreneurial profits[5], defined by Schumpeter as the difference between incomes generated by the redeployment of production factors in new efforts and production costs, will be higher than the 'normal' ones. In fact, Schumpeter (1942) reports that "it is true that there is a real monopolistic gain in these entrepreneurial profits, which are the prices bid by the capitalist society to the successful innovator…".

Thus, for Schumpeter, growth can be explained by the major role of innovation, which generates a 'super-profitability' or monopolistic 'super-profits', associated with higher prices of product and lower process costs. At this level, Schumpeter highlighted the role of giant enterprises. Schumpeter (1942) argues that "we are obliged to recognize that giant enterprises have become the most powerful engine of economic progress and, in particular, of the long run expansion of the total production".

In the Schumpeterian analysis, the economic system does not react passively to these super profits. Indeed, these monopolistic incomes associated with innovation attract imitation, which is immediate, through the diffusion of innovation.

2.1. Innovation-Diffusion: The Source of Growth

In his analysis, Schumpeter refers to innovation and imitation as two dynamic processes operating on individual products composing firms' portfolio rather than on firms themselves. Schumpeter accepts as assumption a dynamic relation between product innovation, realization of a 'super-profitability' on this product and concurrent imitation.

According to the Schumpeterian way of thinking, there are profits from product innovation. These profits are relatively high in the periods following the product introduction, that is to say in the initial stages of competition. Indeed, the new innovated products tend to face a weak competition directly after their introduction and, consequently, can generate high profits. In later stages, the competition of the imitators increases. As the imitative pressures intensify, profits go lower and converge more or less quickly towards normal levels. Therefore, Schumpeter (1950) supports the idea that "the 'super-profitability' of the innovator entrepreneur will persist until the other firms copy its method". The imitation tends to lead the high profits of innovation towards normal levels. Furthermore, Schumpeter (1934) reports that "the entrepreneur... draws the other producers in his branch behind him...they are his competitors, who reduce first and then cancel his profit". Therefore, the profit gained by the entrepreneur disappears almost once the imitation appears (According to Schumpeter, the monopolistic position carried out by the innovator is limited and temporary). More than a simple imitation, competitors will be able to develop a better version of the initial innovation.

Thus, the Schumpeterian analysis is focused on innovation-diffusion as a source of growth. The technical progress, conceived as a linear form process 'Invention => Innovation => Diffusion', plays a role in such a growth. It is a form which has dominated the economic reasoning on the evolution of technology until recently. Considering this process of technological change, the author allowed more importance to innovation than invention and diffusion.

[5] It must be known at this level that the profit of a firm is as important as the quality level of the consumer goods they produce which is high (due to household's preference for quality). However, the higher the number of varieties in force is, the more profits of each monopoly are reduced, regardless of the quality of goods produced (Effect of market sharing).

2.2. The Process of Creative Destruction

The process of technical progress is not necessarily defined by the discontinuity of innovation clusters, which mean groupings of independent companies such as innovative start-ups, small, medium and large firms as well as research organisations, operating in a particular sector or region and designed to stimulate innovative activity. It consists also in a continuous flow of new possibilities and technical improvements, the diffusion of which leads to new innovations. In fact, the technological possibilities remain an unexplored land. Thus, far from being exhausted, the exploration of these technological possibilities can be the source of higher growth.

Seen from this angle, development stimulation is not the result of consumer demand of final products, but the consequence of the industrial and commercial life. Thus, it is not with the older idea that as capitalism makes the new ones, but by eliminating them. So, companies emerge in a process of 'creative destruction' in which many of these firms must perish to establish new ones.

Accordingly, and referring to Schumpeterian logic (Schumpeter, 1942;1950); Mueller (1990) reports that "the creative destruction process proceeds: innovation creates a monopoly, monopoly creates super-profits, super-profits create imitators until the stage of standardized incomes, followed by a new cycle of innovations". Let's note at this level that, according to Schumpeter, the process of 'creative destruction' is the replacement of a product by its improved version (in relation with the quality improvement of the innovated product). That gives to this process a key role in growth.

Consequently, the capitalist system is based on a process of (industrial) change so that industrial revolutions, characteristic of the capitalist process, periodically reorganize the existing industrial structure. Precisely, Schumpeter said that "the capitalist economy is not and cannot be stationary. It is constantly revolutionized from inside by new initiatives, that is to say by the introduction into the productive structure, as it exists at a given time, of new goods or new methods of production or new commercial possibilities". In addition, Schumpeter (1942) argues that "the essential point to retain is that in the treatment of capitalism, we have treated an evolutionary process[6]". This evolutionary character is not due to a quasi-automatic increase of population or capital, but to a qualitative change. Therefore, capitalism is a process of qualitative change.

To sum up, Schumpeter's approach was based on the following ideas:

- The main source of technological progress is innovation;
- Innovations, which lead to the introduction of new processes of production, new products, new methods of management, as well as the implementation of a new organization of production activities, are made by companies, entrepreneurs and researchers, motivated by their own interests and expect to be rewarded by monopolistic incomes in the case of success;
- In general, these monopolistic incomes end up disappearing as one goes along that the processes or products become obsolete when other innovations which compete with technologies arrive in place and chase them from the market: it is the Schumpeterian notion of 'creative destruction';
- The Schumpeterian paradigm of growth stipulates that it results from successive innovations improving quality. These innovations are themselves the result of entrepreneurs' action motivated by the wish to realize super-profits.

Unlike previous models, the Schumpeterian growth model can explain the possibility for developing countries to catch developed countries. It explains also growth in the long run.

2.3. Limits of the Schumpeterian Theory

These limits can be summarized in the following points:

- It turned out that the Schumpeterian theory explains the dynamic of capitalism more than being a theory of economic growth as already understood by economists. Indeed, even if Schumpeter had developed an analysis of the

[6] This is a quotation that is now well known among evolutionary economists.

capitalist system, his analysis was based on a microeconomic reasoning at the level of the innovative firm. The author had not directly treated the issue of economic growth at the macroeconomic level.

- Schumpeter concentrated his analysis more on the major and important innovations, that is to say on those opening new channels, and thus on the revolutionary inventions. So he had underestimated the role of the gradual innovations in the process of technological change, given that it does not reveal a large part in the explanation of scientific and technical ideas that integrated the new processes and products. In fact, although Schumpeter, unlike his predecessors, had distinguished between R&D and knowledge, he had forgotten that technical progress comes from a continuous process of research and gradual accumulation of knowledge, wherein small innovations are often as important as the most revolutionary ones.

- Schumpeter's reflection on the unavoidable extinction of capitalism in the long run and its transformation to socialism seems exaggerated. Indeed, the disappearance of investment opportunities and the decline of the entrepreneurial function had not occurred. Reality has shown that, at the Thirty Glorious, the investment, supported by low real interest rates, played a key role. Moreover, during the 1980s, the entrepreneur's function was rehabilitated. This proves that capitalism is more likely to create welfare and to maintain social order than socialism. Increasing productivity, accordingly, has benefited both entrepreneurs and employees.

Subsequently, one may wonder Schumpeter's analysis has made any gain in capital for the posterior theories? In fact, two very important points have to be mentioned: the technical progress considered as a process in the linear form 'Invention => Innovation => Diffusion', and the process of creative destruction of Schumpeter. These two points were the starting elements for theories which historically followed the Schumpeterian theory, respectively the neoclassical growth theory and the endogenous growth theory.

3. THE NEOCLASSICAL GROWTH THEORY

Solow was one of the first economists to model the process of economic growth. He developed a simple model in which the production of a country is the result of the exploitation of labor force and capital, in a framework of a manufacturing process articulated on the technology used at this precise moment of time. This is the usual formulation of the neoclassical growth model. Its hypotheses are:

- The volume of work is identified by population which grows at an exogenous and constant rate 'n';
- The savings rate 's' is also exogenous and constant;
- As well as technological level 'A';

Thus, it was assumed that labor force growth, saving rate and technology should be measured separately, outside the economic system.

- The markets are competitive and in a situation of equilibrium.

The production level is determined by the production function of a representative firm:

$$Y = AF(K, L) \qquad (1)$$

It's important to remember that, in the neoclassical production function, the technological factor, represented by the coefficient 'A' in the equation (1), was considered as constant and exogenous to the model. Only an external shock could cause a jump in the value of 'A'.

Testing his model, Solow found that the major part of the United States' growth during the XIXth century could not be explained by an increased use of labor force and capital. He attributed this inexplicable 'residual' effect to the technology improvement. Indeed, since the 1950s, economists have attributed a large variation in output per working hour directly or indirectly to technological change, particularly to technical progress (the neoclassical model has shown that technological change must be seriously taken into account in growth models). In this framework, the volume of raw materials used has not changed, but the combination of these raw materials became widely more sophisticated. Thus, according to Solow and the neoclassical model in a general way the technological change would be mainly the source of increasing productivity. It is, therefore, the main determinant of economic growth[7]. So, the question that arises at this level is how to incorporate technological change, despite the fact that the technological factor is always regarded as an exogenous variable in the model?

Setting aside the hypothesis of constant technological level, three types of technical progress had been proposed: neutral in the sense of Hicks, neutral in the sense of Harrod and neutral in the sense of Solow. The technical progress is considered 'neutral in the sense of Hicks' (or output-augmenting) if it does not affect the substitution's marginal rate of capital to labor for a given value of the factorial intensity '$k = K/L$'. Technical progress is said 'neutral in the sense of Harrod' (or labor-augmenting) or 'neutral in the sense of Solow' (or capital-augmenting) according to whether 'capital/production ratio' or 'labor/production ratio' remain constant at the optimum point (Uzawa, 1961). The production function therefore encompasses the technological factor which becomes, in this case, variable over time but remains exogenous to the model. In general, the production function can be written in the following form:

$$Y = F[A^K(t)\,K,\ A^L(t)\,L] \qquad (2)$$

where $A^K(t)$ and $A^L(t)$ are increasing functions of t, positive and superior to 1. Technical progress is said 'neutral in the sense of Harrod' if $A^K(t) = 1$ and 'neutral in the sense of Solow' if $A^L(t) = 1$. On the contrary, technical progress is considered 'neutral in the sense of Hicks' if $A^K(t) = A^L(t)$. Noting $A^K(t) = A^L(t) = A(t)$, the production function becomes:

$$Y = A(t)\,F(K, L) \qquad (3)$$

At this level, the Cobb-Douglas production function with constant returns is often considered:

$$Y = A\,K^{\alpha}\,L^{\beta} \qquad (4)$$

$A > 0$, $0 < \alpha < 1$, $0 < \beta < 1$, α and β represent the output elasticities of capital and labor, respectively.

Since the neoclassical growth model is based on capital accumulation, it stipulates that knowledge creation is critical for long run economic growth. It is certainly the most important proposal which arises from the neoclassic theory of Solow.

This technical progress of the neoclassical growth model is an economic residue. Moreover, it is exogenous, since the capital and labor shares in the total income did not change significantly over time.

In 1957, the contribution of Solow involved separating per capita output variations due to technological change from those due to changes in the availability of per head capital. It is about one of the first empirical studies devoted to the technical progress contribution in growth. In this framework, by using data on the United States over a period of 4 decades, from 1909 to 1949, Solow (1957) noted first that the average rate of technological change in the first half of the period (1909-1929) was smaller than that on the second half of the period (1930-1949). Second, there was evidence that the technological change would have accelerated after 1929. Considering the whole period (4 decades), there was an upward average change of about 1,5% per year. This can be compared to nearly 0,75% per year obtained by Valavanis-Vail (1955) who used a different method over the period 1869-1948. Another possible comparison can be made with the estimates of production per unit of input of Schmookler (1952) showing an increase of 36% in the production per unit of input between the decades 1904-1913 and 1929-1938. Consequently, the upward variation in the production function was, outside the fluctuations, at a rate of almost 1% per year for the first half of the period (1909-1929) and of 2% per year for the second half of the period (1930- 1949). On the whole period, the production per worked hour roughly doubled, thanks to a 87,5% increase attributable to the technological change and 12,5% to the accumulation of the capital. By comparison, Fabricant (1942) found that over the period 1871-1951, nearly 90% of the per capita production increase was attributable to technical progress. Thus, the importance of technical progress in the economic growth is confirmed.

On the other side, a flow of empirical studies dealing with technical progress as a production factor shows that depending on countries, 50% to 75% of economic growth cannot be explained by increasing capital and labor

[7] According to `Solow (1970). improvements in technology have been the real force behind the continually rising standards of living.

exclusively. Specifically, Denison (1967) found, for the American case, that traditional factors (capital and labor) explain only 1/3 of the GDP growth variance. That means that 66% of growth discrepancy remains unexplained. The large size of this residue called 'Solow residue' highlighted the shortcomings of the neoclassical analysis.

Among the limits of the neoclassical growth model is the restriction to consider the technical progress as given, without providing any explanation on the origin of this factor. More precisely, the problem of neoclassical model with the exogenous technological change is that there is no way to compensate for the inputs used to produce the technology. This is because of the equilibrium, materialised by a perfect equality between the selling price of the new product and its marginal cost of production. Indeed, in the equilibrium situation, there is no possibility to improve technology. Thus, the R&D is ignored. Moreover, the fundamental principle of neoclassical model with the exogenous technological change implies that private firms do not devote resources to R&D activities. That's the reason for which this model does not consider that knowledge is provided in a private way. Consequently, according to Solow, if production takes the form '$Y = F(K, AL)$', for a homogeneous production function 'F' of degree 1, where 'K' is capital, 'L' is labor and 'A' is the technological level, the total value of production is paid as compensation to labor and capital. In this context, the Solow model gives us no indication of how the exogenous variables 'n', 's' and 'A' are determined. Therefore, the Ramsey-Koopmans model appears to describe how the savings rate 's' was endogeneized. In this perspective, the savings rate 's' becomes an endogenous variable. Then, endogenous growth models are supposed to examine what are the determinants of technological change.

According to a neoclassical model, the growth pace of an economy is equal to the sum of technical progress rate and the growth rate of active population, determined exogenously. The contribution of this theory is, thus, mainly negative to the extent that the only two long term determinants of growth are out of the model. There is no particular economic factor controlled by any authority having the capacity to sustainably influence long-term growth.

To make growth persistent, an exogenous choc should happen to transform production technology: technical progress. Amable and Guellec (1992) affirm that "the basic model of Solow...is presented in this case as a production representation and medium term adjustments more that a growth theory". With an exogenous technical progress, growth is not caused by the economic system. In other words, given the shortcomings of the neoclassical model, it makes sense to ask whether the 'Solow residue' should be charged to technical progress. This incites the idea of taking into account other factors explaining growth.

One should understand that it will be suitable to go further in the analysis of growth determinants than the Solow analysis in order to consider the technical progress endogenous. By the end of the 1950's, Kaldor (1957) and Arrow (1962) have already tried to analyze the macroeconomic effects of learning phenomena, and more recently, with the emergence of endogenous growth models, Romer (1986) has sought to induce technical progress in growth by supposing that it underwent an induced effect by growth itself.

4. THE ENDOGENOUS GROWTH THEORY

The economic growth theory has known new boom with the formalisation of endogenous economic growth models, notably thanks to Romer (1986); Lucas (1988) and Grossman and Helpman (1994) who are considered as pioneers in the endogenous growth way of thinking. At the origin of this stream is the report of some divergences between the empirical observations and the theoretical results of the growth models established until then. Several hypotheses which underlie the neoclassical growth models have thus been modified to make these models more in accordance with empirical observations.

The endogenous growth theory has assessed the importance of increasing revenues in the economic growth promotion. At this level, the constitution of a historic frame requires consideration of many analyses, which have historically evolved from the analysis of Young (1928) until the new growth theories.

4.1. The theory of Young (1928)

Although Ramsey (1928) made an important contribution to explain production growth, the contribution of Young in the same year was quite different and it was considered as precursor of what is called 'modern endogenous growth theories'.

In this framework, Young (1928) focused on two points:

- Initially, and the most important, the increasing incomes are manifested in the capitalist economies or the economies adopting an indirect production method;
- Then, increasing revenues due to capital accumulation externalities are considered as a strong source of progress as well as of economic growth, even in the absence of growth in the labor force and technical progress due to new invention or application of the knowledge base. In other words, even with a stationary population and in the absence of new discoveries in pure or applied knowledge, there is no limits to the economic growth process.

However, such economic progress due to increasing incomes faces the following challenges:

- First, the resources cannot be easily transferred from a production activity to other production activities;
- Then, there is a minimum level of capital required to accumulate savings.

To overcome these problems, Young (1928) supported the idea that an investment above a critical minimum threshold of capital accumulation is required to generate externalities, and therefore increasing incomes. Pending the achievement of this objective, Young (1928) argued that the discovery of new natural resources, population growth and technical progress play their own role in the overcoming of previous problems, and allow an industry to reach the stage in which it can achieve savings. However, Young (1928) believed that the market size is the most important factor that allows an industry to realize externalities. Young (1928) asserts that "the only most important factor to determine the industry's efficiency seems to be the market size". Moreover, Young (1928) reports that "the market size is determined and defined by the volume of production".

In sum, according to Young (1928) economic growth is explained by increasing incomes due to capital accumulation externalities, new natural resources, population growth, technical progress and, most importantly, market size.

4.2. The Kaldor-Verdoorn Law

None of the endogenous growth models have recognized the simple empirical tests made by Verdoorn in the 1950s and Kaldor in the 1960s showing the existence of increasing incomes in the industrial economies.

In this framework, Verdoorn (1949) extended the analysis of Fabricant (1942) on the American productivity growth, but has provided, in a more important way, the foundations for the 1960s Kaldor and Salter analysis on the British productivity growth.

Later, the model of Kaldor (1966) has recognized the importance of endogenously determined technological change and technological knowledge, but has emphasized the importance of a developed market to explain the presence of rising incomes. The empirical analysis of economic growth of Kaldor is generally viewed as being macroeconomic. The reason is that economies of scale are generated endogenously through technological change and technological knowledge. They undoubtedly appear inside the firm, but as Adam Smith showed, new products and processes can appear because of the expansion of the market. Firms and industries grow at different rates, but the effective demand growth will stimulate product innovations and thus improvements in labor productivity[8]. Kaldor (1966) recognized that these economies of scale depend on the industry structure, but he paid a special attention to the dynamic and macroeconomic nature of the increasing incomes as described by Young (1928).

[8] Kaldor (1966) particularly emphasized the differences in productivity growth across countries, arguing that these differences are best explained by changes in the increase of the demand.

The Kaldor-Verdoorn law states, as Verdoorn (1949) originally asserted, that productivity growth rates are positively and linearly correlated with those of production. Moreover, Kaldor (1966) confirmed that the production growth is an important determinant of the growth in productivity and the increase in employment. Specifically, for each increase by a percentage point in production, the labor productivity and the employment increase by almost 0,5 percentage point. This suggests that endogenous technological change and technological knowledge explain the larger part of production growth. It should be noted that the Kaldor-Verdoorn law had continued to be strongly held in the 1990s.

4.3. The AK theory

The first variant of the endogenous growth model, called 'AK theory', was presented by Frankel (1955). Then, the famous articles of Romer (1986) and Lucas (1988) gave the modern formulation of this contribution, which had been long neglected. Essentially, the AK model considered knowledge as a particular type of capital: knowledge creation is a direct result of the capital accumulation by different companies. The basic idea behind this proposal is that accumulation of capital contributes to the collective creation of new technological and organizational knowledge through learning by doing and imitation. This creation of knowledge will permanently compensate for the reduction of the marginal productivity of capital and will thus make it possible for the economy to maintain a positive growth rate in the long run, under suitable hypothesis concerning the externalities of the learning.

Rebelo (1991) is considered as the reference matrix of endogenous growth theory although it came later than the first model dealing with endogenous growth (Romer, 1986; Lucas, 1988). This model explains the real contribution of endogenous growth as well as the main characteristics necessary to obtain a growth process called 'self sustained growth process'. In fact, long run growth is now determined inside the model and not outside of it by growth of an exogenous variable. Rebelo (1991) proposed the simplest version of a production function characterised by the absence of declining capital productivity and by no more cancellation of marginal productivity of capital when the capital stock become large. Growth rate expression becomes:

$$\gamma_k \quad = \quad sA-(n+\delta) \tag{5}$$

As y = Ak and c = (1-s)y, one can deduct that the per capita product growth rate and the per capita consumption growth rate are equal. Growth rate depends positively on technology characteristics as well as on savings rate and negatively on population growth rate and on capital depreciation.

Given this new equation, we can provide answers to questions that the Solow model cannot treat. The most important one is related to the fact that an economy described by the AK technology can have a positive long run per capita growth rate independent from any technical progress (as shown in figure 1, in the case where $sA > n + \delta$). This long term growth rate is likely to depend on behavior parameters of the model, the savings rate in particular. A rich country and a poor one, having the same technology and the same savings rate, but having different initial capital stock, will have the same growth rate. Here, with Rebelo model, there is no mechanism allowing convergence between rich and poor countries.

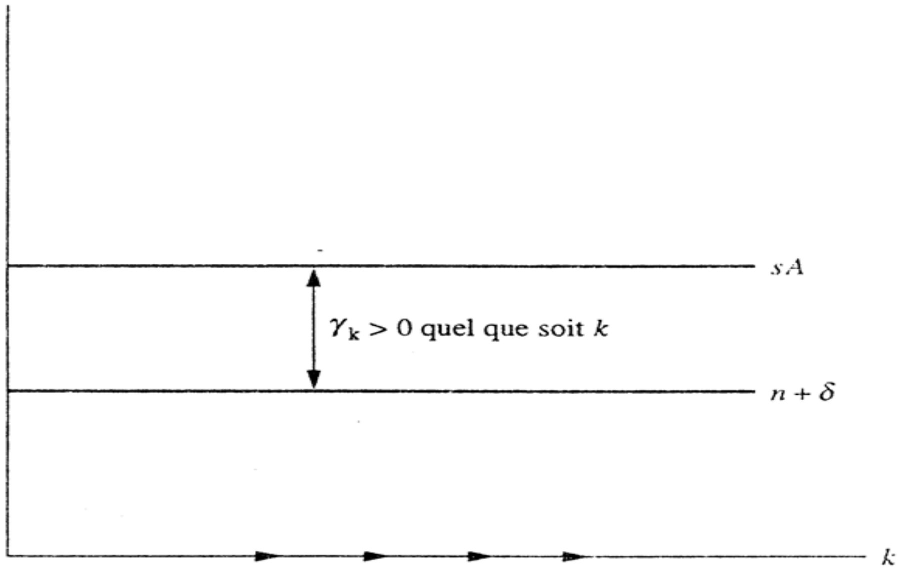

Figure-1. "AK" model

Source: Rebelo (1991)

In addition, this model, by its specific parameters, allows the State to intervene and to act on the growth rate. Indeed, a policy aiming to increase the savings rate will have a permanent positive effect on growth.

An unhappy prediction of the AK endogenous growth model, in which knowledge is regarded only as capital, is that a long run positive growth is not compatible with a possible convergence between various countries. Moreover, it cannot give an account for the possibility of maintaining a positive and optimal growth in an economy where accumulation of capital requires the use of a non-renewable resource. Indeed, the only way of counterbalancing the exhaustion of natural resources and of maintaining a positive growth in the long run consists in involving technical progress. However, as much as the accumulation of capital remains the only engine of new knowledge in this model, the acceleration of technical progress would lead an increased exhaustion of the natural resource, which can only compromise the growth prospects in the long term, in other words to aggravate the problem which technical progress has to lighten. More fundamentally, focusing on the role of the global supply of savings in growth, the AK model neglects the demand and, more specifically, the role of entrepreneurs, institutions and economic policies that will enhance productivity by promoting the incentives of entrepreneurs to innovation.

The growth models based on the accumulation of capital, such as the neoclassical growth model and the AK model, cannot explain, at the same time, the long run growth and the convergence of various countries, i.e. institutions were omitted in the AK model analysis.

4.4. The Theory of Arrow (1962)

There were few explanations for the technological change, one of which is the approach of 'learning-by-doing' of Arrow (1962). This approach assumed that new knowledge, acquired thanks to the accumulation of capital, can increase work efficiency. In other words, in a production process, as time passes, laborers become more productive thanks to the acquired experience (learning-by-doing process).

On the other hand, Arrow (1962) was one of the first economists to endogeneize technological change, resulting from investment in R&D. In this framework, endogenous growth theory started from a basic hypothesis: the supply of labor and of capital determine the output growth. Most endogenous growth models have introduced some variables external to the firm such as R&D, which helps to overcome supply constraints and to support growth in the long run.

Arrow (1962) has found a classical result: firms tend to under-invest in R&D when knowledge spillovers are important or when competitors can capture any new knowledge created easily or at reduced price. However, firms can internalize such externalities through cooperation in R&D (R&D alliances) and earn higher incomes than under the non-cooperation. Such cooperation is part of cooperative agreements policy in R&D. Such a policy, considered as a modality to internalize the externalities specific to R&D, takes the form of a convention according to which firms decide to share the R&D costs or costs associated to information or both. At the end of this cooperation, companies taking part in the agreement will then keep competing on the products' market each on its side, they commercialize the final product resulting from the common innovation, carrying out higher incomes.

It should be noted that this cooperation in R&D is more remarkable in sectors of high technology, due to increasing research costs and growing technological uncertainty. This trend has stimulated a theoretical literature dealing with motivations for inter-firm cooperation in R&D, trust in particular. Indeed, trust becomes necessary to justify the engagement of firms in a cooperation in R&D and to contribute to their success. Trust is defined as the belief of each firm that its potential collaborator will respect the contract.

4.5. The Endogenous Growth Theory of the 1980s

The main contribution on endogenous growth, especially by Romer (1986) and Lucas (1988) aims to endogeneize the source of growth sustained in per capita income, namely the accumulation of knowledge. There are many channels through which firms accumulate knowledge including education, basic scientific research, learning-by-doing, and process and product innovations.

In this framework, by the middle of the 1980s, Romer (1990) and other authors contributions were based on three principles:

1) Technical progress is at the heart of economic growth. It leads to growth. In other words, growth is fundamentally driven by the accumulation of technology;

2) Technical progress occurs in large part because of intentional actions taken by economic actors responding to market stimulants. Therefore, it is about an endogenous rather than exogenous technical progress, i.e. it constitutes a by-product of the economic activity and figures among the fundamental sources of growth. Being endogenous also means that the innovation process is rooted in each country or region;

3) Technology is a non-rivalled input in the production.

Moreover, this endogenous growth model takes into account the fact that technology is exclusive or at least partially exclusive. That means that technology is far from being a public good at this level. As a result, only endogenous growth model takes into account the role of patents in growth. Indeed, the patent system, as a form of intellectual property rights protection, may be a solution to the non-exclusivity. To support their point of view, the partisans of endogenous growth model showed that the United States, exasperated to see that they had lost their technological advance, tried to prevent their competitors, in particular Japan and the new industrialized countries (NICs) of rapid growth, from free access to American technology. At this level, the American government obtained, in Uruguay Round of General Agreement on Tariffs and Trade (GATT) negotiations, the adoption of rules protecting the intellectual property. This was considered as an important reversal in the economic policy, a reversal revealing the importance of technology as a fundamental source of a country's prosperity.

Consequently, we have crossed a second major stage towards an analysis closer to reality, by abandoning the unrealistic hypothesis that knowledge and technology are free and universally available. In this context, important innovations are characterized by an exclusive use, even if it is temporary[9]. Commercial secrets, copyrights and essentially patents constitute the most common means to prevent others from using the new process or product, and to ensure that the inventor can benefit alone from his invention. In this case, the owner of the exclusive

[9] The widely recognized role of the patent is precisely to provide a monopoly on the use of a non-rivalled input (the technology, and consequently the design of the new product) for a certain period of time (the inventor retains control of his invention for only a number of years). Consequently, improvements in technology must confer benefits that are at least partially exclusive, insofar as the owner of the technology cannot prevent others from using that to some extent.

technology enjoys a competitive advantage allowing him to charge higher prices and to earn monopolistic profits, more important than the marginal costs of production of the new product, and which consequently provide a path to compensate for the production costs of technology, or R&D costs.

In this context, despite the apparent importance of R&D, few attempts were made to give this variable a fundamental role in a growth model. However, the endogenous growth model (Romer, 1986) takes into account the role of R&D. At this level, many economists believe that R&D spending is an important determinant of growth in the long run. Funds injected in R&D[10] and the flow of innovations related to these funds is reflected in sustained improvement of products' quality. Furthermore, the increase in productivity makes it possible for the economy to grow at a rate determined by the degree of R&D investment.

- The importance of the role of human capital

According to the human capital approach (Cohen and Levinthal, 1989) new knowledge or new technologies result from R&D investment, that is to say investment in human capital, in the use of specialized human resources and in equipment.

Thus, it is supported that there is an important role of human capital in an endogenous growth model. Then, it is important to ask how to model human capital? Referring to the concept of 'human capital', Lucas (1988) has integrated in his model the individual decision to acquire knowledge. By human capital, he referred to laborers' general knowledge level. There are two effects of human capital on production. First, the level of human capital incorporated in a firm j affects positively its productivity: that is the 'internal effect'. Second, the increase in the average level of human capital which enhances the productivity of the economy as a whole: this is called 'external effect'. Lucas thus introduced the effect of overflows at two levels. Given the assumption that the volume of labor remains constant, the production function can, in this perspective, take the following form:

$$Y_j = A(H)\, F(K_j, H_j) \qquad (6)$$

Where K_j and H_j represent respectively the physical capital stock and the human capital stock employed in j, and H represents the aggregate level of human capital[11]. Assuming that human capital is incorporated in individual, the human capital stock can be expressed as a multiple of labor factor. In this case, we have the following production function:

$$Y = F(K, hL) \qquad (7)$$

Where h is a coefficient reflecting the human capital stock. This formulation can be considered as an extension of the production function of type 'labor-augmenting'.

Thus, the main conclusion at this level is that the human capital stock determines the production growth rate. Indeed, the most recent endogenous growth models have focused on the human capital stock as an important input in invention and technological change, and consequently in the explanation of the production growth rate. As literacy is the only measure of human capital, the initial level of literacy can be important to understand growth. In this framework, Romer (1990) showed that a change in the level of literacy, as the only measure of human capital growth rate, was likely to influence the production growth rate between 1960 and 1980. More precisely, it was shown that an increase in the literacy rate from an average of 50% to 60% was associated with an increase of investment share in GDP from an average of 14% to 16%. This shows that literacy has economically significant effects.

At this level, according to Romer (1990) human capital combines three types of knowledge:

- The physical skills such as work force;

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[10] Romer recognized that these funds are of the order of 2% to 3% of Gross National Product (GNP) in industrialized countries.

[11] H may be measured as the weighted sum of schooling duration corresponding to different levels of schooling, with, as coefficient of weighting, the population share for which the considered level is the highest reached before leaving any schooling stream.

- Knowledge acquired in primary and secondary levels: The basic role of education in this two levels is to produce basic knowledge such as the ability to read or solve an equation; and
- Scientific knowledge acquired in post-secondary education, measured by years of post-secondary studies.

These types of knowledge are primarily in mathematics and sciences. According to Romer (1990) the concentration on these two fields corresponds to the importance of R&D activities as a source of growth.

For these various types of knowledge to be well printed in the human capital, it is necessary that the country has powerful educational systems, materialized by a schooling of important quantity (measured by the number of years studied and the length of the school year) and quality (measured by the student-teacher ratio, the class size, the characteristics of teachers, the resources devoted or available to educational establishments and the organisational structure of these institutions). Thus, according to Levine and Renelt (1992) the quantity and the quality of schooling explain around 40% of production growth rates variation, as it is the case of the East Asian countries like Singapore, Hong-Kong, South Korea,… The basic conclusion remains that the improvements in education set off an improvement in the economic growth. Thus, it is possible to define the overall production of consumer goods in an economy as a function not only of labor, physical capital and experience, but also of education. In this case, this production increases more than proportionally as far as these inputs increase.

In sum, the endogenous growth model, integrating a quite realistic mechanism about the knowledge and technology creation, simply assumes that the overall economic output is not the result of a simple combination of inputs used by companies (Human capital, R&D inputs, labor force and physical or productive capital)[12]. It is also the result of R&D work undertaken by the whole companies' environment (educational system).

Thus, three great ideas are the basis of what is called 'new growth theories':

- Growth is mainly stimulated by the rate of technological innovations, in a form of new products, new methods and new ways of organizing the production processes;
- Most of innovations result from the activities of entrepreneurs or investments, generally from investments in R&D, and comprise risks related to experimentation and learning;
- The motivation to invest in innovation is itself influenced by the economic environment. Moreover, during these last years, a new wave of growth models have emerged, in which the economic growth is induced not only by the accumulation of capital and saving, but more basically by entrepreneurs and innovation activities, which themselves are stimulated or facilitated by various characteristics of the institutional environment, among which the intellectual property rights protection, subsidies allowed to innovating activities, market competition, macroeconomic volatility, the supply of skilled labor force or the effectiveness of research,…. All these parameters have more or less important effects on growth. The new paradigm of growth can easily be developed in order to consider the institutional transformations as endogenous and to connect them to endogenous technical progress.

In contrast with the previous growth models based on capital accumulation, new growth theories may provide an explanation for both the differences in long run growth rates and the possibility of convergent evolutions. As far as these models give much importance to institutions, they do not deviate significantly from economists' traditional concerns. It could be argued that these new growth theories remain not useful enough to formulate development policies: as far as they seem to suggest the same policy for all countries, whatever their level of development, and in particular whatever their macroeconomic stability, their respect of the property rights, the excellence of their educational system and also the development of their financial system and its capacity to attract savings as well as its risk-taking strategy.

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[12] Lucas (1988) divided the variable 'Capital' in two parts: the first one corresponds to 'physical capital' and the second one represents the 'human capital', while assuming, like Romer (1986) that production increases more than proportionally with the increase of physical capital and human capital taken together.

Benhabib and Spiegel (1994) give some proof to the robustness of the relationship between education and growth. They found this result after estimating, in a first step, a growth equation with first differences variables near to Mankiw *et al.* (1992) for the period between 1965 and 1985. In this equation, variable reflecting skills' stock has a not statistically significant negative coefficient. That's why the authors proposed to modify the growth equation specification in the way to present explicitly the skills' effect on the technological catching process and to drop the technological proximity hypothesis which is necessary to the Mankiw *et al.* (1992). That leads to add a term depending jointly on the human capital stock and the initial level of technology. Benhabib and Spiegel (1994) confirmed that the interaction between education and technological gap is likely to be a determinant variable of economic performance of a given country.

In the same line of this study, other empirical research has revealed other mechanisms allowing skill formation to have an indirect effect on growth. Indeed, human capital accumulation was not a sufficient guarantee of economic take off, which requires investigating its articulation with other economic policies. Some empirical research (Benhabib and Spiegel, 1994) found that human capital accumulation stimulates investment and that it has close relationship with economic openness or that education has a significant relationship with R&D activities.

4.6. The Neo-Schumpeterian Endogenous Growth Theory in the Aghion-Howitt Study of the 1990s

Aghion and Howitt (1992) presented an economic growth model based on the process of creative destruction of Schumpeter. Following Schumpeter, the model supposed that the individual innovations affect significantly the whole economy. The authors consider the period between two successive innovations. Each period length is random because of the stochastic nature of the innovation process. The relation between research amounts during two successive periods is significant as far as the research amount during any period depends on the one expected in the next period. More precisely, the amount of current research depends negatively on the amount of the expected research for the next period. One source of this inter-temporal relation is the creative destruction. At this level, the outcome of current research is a prospect for the monopolistic rents for the next period. The latter will last only until the next innovation takes place, i.e. the time that the technological knowledge underlying rents will be obsolete. Obsolescence shows an important general feature of the growth process, namely that progress creates both gains and losses. Therefore, the expected present value of rents depends negatively on the next innovation. Thus, the prospect for further future research will discourage current research because it will destroy rents created by current research, taking into account the erosion process of monopolistic rents associated with innovation.

This neo-Schumpeterian endogenous growth model in the Aghion-Howitt of 1990s takes into account the fact that the vertical innovations, generated by a competitive research sector, constitute a source of growth. In this framework, Aghion and Howitt (1992) examined a channel that has received little attention in the literature of endogenous growth, namely industrial innovations, which improve products' quality. This channel introduces the obsolescence factor in the endogenous growth theory; the best products make the old products obsolete.

In sum, according to Aghion and Howitt (1992) growth results exclusively from technical progress, resulting in its turn from a research competition among firms generating innovations. Every innovation consists of a new intermediate good that can be used to produce a final product more efficiently than before[13]. The research firms are motivated by the prospect of monopolistic rents that can be earned when a successful innovation is patented. However, these rents will be destroyed by the next innovation, which will make obsolete the existing intermediate good.

[13] Other papers in the endogenous growth literature having modelled vertical innovations of product include Segerstrom, Anant and Dinopoulos (1990). In addition, Grossman and Helpman (1991) constructed a model of vertical innovation of product that explicitly integrates the analysis of Segerstrom, Anant and Dinopoulos (1990) with the approach of Aghion and Howitt (1992).

While the innovator in place has a monopoly power over the use of his innovation, the knowledge included in this innovation could be accessible to all the producers undertaking R&D activities, and seeking to innovate. This refers to the concept of 'R&D externalities', which can be both domestic and international (mainly North-North and North-South). This concept of 'R&D externalities' focuses on the role of technical progress in economic growth, taking into account what is called 'absorptive capacity'. At this level, Abramovitz (1986) first introduced the concept of 'social capability' which means that an economy must have some basic capabilities to benefit from foreign technology, including the absorptive capacity which was introduced by Cohen and Levinthal (1990). Therefore, these authors have defined this capacity as "the ability of a firm to recognize, assimilate and apply new, external, information, for commercial purposes". Moreover, since innovation is a key success factor in organizations, the absorptive capacity is also one of most important concepts that emerged in the field of organizational research in the past years. In this context, Cohen and Levinthal (1990) adjusted the concept at the organizational level, considering that "absorptive capacity of an organization will depend on the absorptive capacity of its individual members". Later, most authors have proposed only minor changes to the definition proposed by Cohen and Levinthal (1990). Therefore, Dahlman and Nelson (1995) defined the national absorptive capacity as "the ability to learn and implement technologies and practices already associated to developed countries". In other words, it is the ability of a country to identify and absorb technological knowledge produced outside the country. Finally, Zahra and George (2002) extended the absorptive capacity theory introduced by Cohen and Levinthal (1990) by specifying four distinct dimensions of this capacity: acquisition, assimilation, transformation and exploitation. Thus, Zahra and George (2002) defined it as "a set of organizational routines and processes by which firms acquire, assimilate, transform and exploit external knowledge to produce a dynamic organizational capacity related to the creation and use of knowledge, which strengthens the ability of a firm to gain and sustain a competitive advantage". By defining the absorptive capacity as a dynamic capability, Zahra and George (2002) highlighted its strategic nature.

Although there is no consensus on a definition of absorptive capacity, we can simplify by considering that the latter is basically the ability of an organization to use external knowledge in a commercial way.

Despite the growing popularity of the absorptive capacity use, empirical research dealing with it was limited by a lack of a clear definition of this concept (Lane *et al*., 2006). However, a large number of empirical studies[14] have mainly focused on the positive, direct and individual effect that absorptive capacity has on the overall firm performance. Moreover, this firm performance is affected by the co-evaluation of the absorptive capacity and other dynamic abilities of the firm such as learning abilities. Specifically, according to Cohen and Levinthal (1990) the absorptive capacity is the result of the firm efforts to increase its learning capacities, which involve a better ability to assimilate the existent knowledge.

Based on the arguments presented by Cohen and Levinthal (1990) the most commonly used indicators for such capacity are related to R&D activities. Specifically, researchers having studied the possibilities for increasing organizational absorptive capacity[15] suggested R&D as an important factor. However, empirical research has not fully supported this assumption. The results showed, therefore, that R&D is not significant in different circumstances and for all types of knowledge (Grünfeld, 2004; Schmidt, 2005). R&D is less likely to influence the absorptive capacity of small organizations (Jones and Craven, 2001). Therefore, some researchers have changed their interest[16] from this traditional indicator and have focused on human resources involved in the process.

Since empirical research does not confirm the influence of these determinants, namely R&D and human capital, the absorptive capacity measure through these determinants remains questionable although it was commonly

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[14] DeCarolis and Deeds (1999). Lane, Salk and Lyles (2001). Tsai (2001). George, Zahra, Wheatley and Khan (2001) and Jansen, Van den Bosch and Volberda (2005).

[15] Rocha (1999). Kamien and Zang (2000). Knudsen, Dalum and Villumsen (2001). Griffith, Redding and Reenen (2004). Grünfeld (2004). Escribano, Fosfuri and Tribo (2005). Kneller and Stevens (2006) and Mancusi (2008).

[16] For example, Mangematin and Nesta (1999). Kneller and Stevens (2006) and Vinding (2006).

performed. Therefore, according to Schmidt (2005) it is more convenient to measure the absorptive capacity through its results. In this context, the absorptive capacity is an important determinant of innovation. Thus, according to Cohen and Levinthal (1990) the absorptive capacity is also fundamentally linked to the firm's innovative capabilities and its ability to commercially exploit a particular new knowledge. Specifically, according to Cohen and Levinthal (1990) the absorptive capacity depends mainly on basic knowledge of the existent organization and is the key to organizational innovation. Furthermore, according to Lane *et al.* (2002) the absorptive capacity is expected to increase the speed, frequency and value of innovation and, at the same time, innovation products knowledge, which becomes part of the organizational absorptive capacity. In addition, the influence of the latter on innovation has been studied empirically by several authors[17]. In these flows of research, there has been a distinction between the product innovation and the innovation process. Therefore, there was an analysis of the influence of the absorptive capacity on both parts. In this context, Cantner and Pyka (1998) showed that the development of absorptive capacity is a superior strategy for the accumulation of external knowledge for innovation process and product innovation. In other words, this capacity has a strong positive influence on both elements. Specifically, its influence on the product innovation which is even stronger than on the innovation process.

5. CONCLUSION

By tracing the historical evolution of the literature on economic growth, since the Schumpeterian theory till new growth theories, we can conclude that the representation of technical progress has significantly developed in the way that just little remains to be retained from the analysis of Schumpeter. Thus, it was found firstly that technical progress has been adopted by Schumpeter while ignoring patents as well as other forms of intellectual property rights protection, human capital and therefore education, and institutions. Then, the process of creative destruction of Schumpeter ignores a very important factor namely the 'obsolescence factor'. Finally, Schumpeter did not define explicitly the concept of 'R&D externalities' ignoring thus absorption capacity. All these factors neglected by Schumpeter compromise the robustness of his analysis and leave the field for the endogenous growth theory, in particular the endogenous growth theory of the 1980s and the neo-Schumpeterian endogenous growth theory of the 1990s, which treated all these subjects.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

REFERENCES

Abramovitz, M., 1986. Catching up, forging ahead, and falling behind. Journal of Economic History, 46(2): 385-406. *View at Google Scholar* | *View at Publisher*

Aghion, P. and P. Howitt, 1992. A model of growth through creative destruction. Econometrica, 60(2): 323-351. *View at Publisher*

Amable, B. and D. Guellec, 1992. The theories of endogenous growth. Political Economy Review, 102(3): 317-337.

Arrow, K., 1962. Uncertainty and the welfare economics of medical care. American Economic Review, 53(5): 941-973.

Benhabib, J. and M. Spiegel, 1994. The role of human capital in economic development: Evidence from aggregate cross–country data. Journal of Monetary Economics, 34(2): 143-173. *View at Google Scholar* | *View at Publisher*

Cantner, P. and A. Pyka, 1998. Absorbing technological spillovers: Simulations in an evolutionary framework. Industrial and Corporate Change, 7(2): 369-397. *View at Google Scholar* | *View at Publisher*

Cohen, W.M. and D.A. Levinthal, 1989. Innovation and learning: The two faces of R&D. Economic Journal, 99(397): 569-596. *View at Google Scholar* | *View at Publisher*

[17] For example, Cohen and Levinthal (1990). Knudsen, Dalum and Villumsen (2001). Schmidt (2005). Vinding (2006) and Mancusi (2008).

Cohen, W.M. and D.A. Levinthal, 1990. Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly, 35(1): 128-152. *View at Publisher*

Courvisanos, J., 2009. Political aspects of innovation. Research Policy, 38(7): 1117-1124. *View at Google Scholar* | *View at Publisher*

Courvisanos, J., 2010. Political aspects of innovation in an ecologically unsustainable world. Revised Paper Initially Presented at the Spirit of Innovation IV, Forum: Environment, Innovation and Sustainable Development, Euromed Management School, Marseille.

Dahlman, C.J. and R.R. Nelson, 1995. Social absorption capability, national innovation systems and economic development, in B. Koo and D. Perkins (eds), Social Capability and and Long-Term Economic Growth. London: Macmillan. pp: 82-122.

DeCarolis, D. and D. Deeds, 1999. The impact of stocks and flows of organizational knowledge on firm performance: An empirical evaluation of the biotechnology industry. Strategic Management Journal, 20(10): 953-968. *View at Google Scholar* | *View at Publisher*

Denison, E., 1967. Why growth rates differ? , Washington D.C: The Brookings Institution.

Escribano, A., A. Fosfuri and J. Tribo, 2005. Managing knowledge spillovers: The impact of absorptive capacity on innovation performance. Retrieved from http://www.fep.up.pt/conferences/earie2005/cd_rom/Session%20V/V.M/ESCRIBAN.pdf [Accessed 5.6.2006].

Fabricant, S., 1942. Employment in manufacturing, 1899-1939: An analysis of its relation to the volume of production. New York: NBER.

Frankel, M., 1955. Obsolescence and technological change in a maturing economy. American Economic Review, 46(3): 296-319. *View at Google Scholar*

George, G., S.A. Zahra, K.K. Wheatley and R. Khan, 2001. The effects of alliance portfolio characteristics and absorptive capacity on performance: A study of biotechnology firms. Journal of High Technology Management Research, 12(2): 205-226. *View at Google Scholar* | *View at Publisher*

Griffith, R., S. Redding and J.V. Reenen, 2004. Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. Review of Economics and Statistics, 86(4): 883-895. *View at Google Scholar* | *View at Publisher*

Grossman, G.M. and E. Helpman, 1991. Innovation and growth in the global economy. Cambridge: MIT Press.

Grossman, G.M. and E. Helpman, 1994. Endogenous innovation in the theory of growth. Journal of Economic Perspectives, 8(1): 23-44. *View at Google Scholar*

Grünfeld, L.A., 2004. The multiple faces of R&D: Absorptive capacity effects and different sources of spillovers. Oslo: Norwegian Institute of International Affairs.

Jansen, J.J.P., F.A.J. Van den Bosch and H.W. Volberda, 2005. Managing potential and realized absorptive capacity: How do organizational antecedents matter? Academy of Management Journal, 48(6): 999-1015. *View at Google Scholar* | *View at Publisher*

Jones, O. and M. Craven, 2001. Absorptive capacity and new organisational capabilities: A TCS case stud. Manchester Metropolitan University Business School Working Paper Series No. 01/02.

Kaldor, N., 1957. A model of economic growth. Economic Journal, 67(268): 591-624.. *View at Google Scholar* | *View at Publisher*

Kaldor, N., 1966. Causes of the slow rate of economic growth of the United Kingdom. An inaugural lecture. London: Cambridge University Press. pp: 40.

Kamien, M.I. and I. Zang, 2000. Meet me halfway: Research joint ventures and absorptive capacity. International Journal of Industrial Organisation, 18(7): 995-1012. *View at Google Scholar* | *View at Publisher*

Kneller, R. and P.A. Stevens, 2006. Absorptive capacity and frontier technology: Evidence from OECD manufacturing industries. Oxford Bulletin of Economics & Statistics, 68(1): 1-21. *View at Google Scholar* | *View at Publisher*

Knudsen, M.P., B. Dalum and G. Villumsen, 2001. Two faces of absorptive capacity creation: Access and utilisation of knowledge. Aalborg: DRUID.

Lane, P.J., K. Balaji and P. Seemantini, 2002. A thematic analysis and critical assessment of absorptive capacity research. Boston, Academy of Management Proceedings, 2002(1): M1-M6. *View at Google Scholar* | *View at Publisher*

Lane, P.J., B. Koka and S. Pathak, 2006. The reification of absorptive capacity: A critical review and rejuvenation of the construct. Academy of Management Review, 31(4): 833-863. View at Google Scholar | View at Publisher

Lane, P.J., J.E. Salk and A. Lyles, 2001. Absorptive capacity, learning and performance in international joint ventures. Strategic Management Journal, 22(12): 1139-1161. View at Google Scholar | View at Publisher

Levine, R. and D. Renelt, 1992. A sensitivity analysis of cross-country growth regressions. American Economic Review, 82(4): 942-963. View at Google Scholar

Lucas, R.E., 1988. On the mechanics of economic development. Journal of Monetary Economics, 22(1): 3-42. View at Google Scholar

Mancusi, M.L., 2008. International spillovers and absorptive capacity: A cross-country, cross-sector analysis based on European patents and citations. Journal of International Economics, 76(2): 155-165. View at Google Scholar | View at Publisher

Mangematin, V. and L. Nesta, 1999. What kind of knowledge can a firm absorb? International Journal of Technology Management, 18(3/4): 149-172. View at Google Scholar | View at Publisher

Mankiw, N.G., D. Romer and D.N. Weil, 1992. A contribution to the empirics of economic growth. Quarterly Journal of Economics, 107(2): 407-437. View at Google Scholar | View at Publisher

Mueller, D.C., 1990. The dynamics of company profits: An international comparison. Cambridge: Cambridge University Press.

OECD, 1992. Technology and the economy – the key relationships. Report on the Technology/Economy Programme. Paris, OECD.

Ramsey, F.P., 1928. A mathematical theory of saving. Economic Journal, 38(152): 543-559. View at Google Scholar | View at Publisher

Rebelo, S., 1991. Long-run policy analysis and long-run growth. Journal of Political Economy, 99(3): 500-521. View at Google Scholar | View at Publisher

Rocha, F., 1999. Inter-firm technological cooperation: Effects of absorptive capacity, firm-size and specialization. Economics of Innovation & New Technology, 8(3): 253-271. View at Google Scholar | View at Publisher

Romer, P.M., 1986. Increasing returns and long run growth. Journal of Political Economy, 94(5): 1002-1037. View at Google Scholar | View at Publisher

Romer, P.M., 1990. Endogenous technological change. Journal of Political Economy, 98(5, Part 2): S71-S102. View at Google Scholar | View at Publisher

Romer, P.M., 1990. Human capital and growth: Theory and evidence. Carnegie-Rochester Conference Series on Public Policy, 32(1): 251-286. View at Google Scholar | View at Publisher

Schmidt, T., 2005. What determines absorptive capacity? Copenhagen, DRUID Summer Conference.

Schmookler, J., 1952. The changing efficiency of the American economy, 1869-1938. Review of Economics and Statistics, 34(3): 214-231. View at Google Scholar | View at Publisher

Schumpeter, J.A., 1934. The theory of economic development. An inquiry into profits, capital, credit, interest, and the business cycle. Cambridge: Harvard University Press. pp: 255.

Schumpeter, J.A., 1942. Capitalism, socialism and democracy. 1st Edn., New York: Harper & Brothers.

Schumpeter, J.A., 1950. Capitalism, socialism and democracy. 3rd Edn., New York: Harper & Brothers.

Segerstrom, P., T. Anant and E. Dinopoulos, 1990. A schumpeterian model of the product life cycle. American Economic Review, 80(5): 1077-1091. View at Google Scholar

Solow, R.M., 1957. Technical change and the aggregate production function. Review of Economics and Statistics, 39(3): 312-320.

Solow, R.M., 1970. Growth theory: An exposition. New York: Oxford University Press.

Tsai, W., 2001. Knowledge transfer in intra-organizational networks: Effects of network position and absorptive capacity on business unit innovation and performance. Academy of Management Journal, 44(5): 996-1004. View at Google Scholar | View at Publisher

Uzawa, H., 1961. Neutral inventions and the stability of growth equilibrium. Review of Economic Studies, 28(2): 117-124. View at Google Scholar | View at Publisher

Valavanis-Vail, S., 1955. An econometric model of growth, U.S.A., 1869-1953. American Economic Review, 45(2): 208-221. View at Google Scholar

Verdoorn, P.J., 1949. Factors that regulate the development of labor productivity. L'Industria, 1: 3-10. View at Google Scholar

Vinding, L.A., 2006. Absorptive capacity and innovative performance: A human capital approach. Economics of Innovation and New Technology, 15(4/5): 507-517. View at Google Scholar | View at Publisher

Von Tunzelmann, G.N., 1995. Technology and industrial progress: The foundations of economic growth. United Kingdom: Edward Elgar Publishing Ltd.

Young, A.A., 1928. Increasing returns and economic progress. Economic Journal, 38(152): 527-542.

Zahra, S.A. and G. George, 2002. Absorptive capacity: A review, reconceptualization, and extension. Academy of Management Review, 27(2): 185-203. View at Google Scholar | View at Publisher