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Knowledge and Technological Change in Different Schools of Economic Thought
(A Brief Historical Review)

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Summary

A thorough analysis of current capitalism requires a proper understanding of the dynamics of technological changes and its effects on the economy. Innovation is fundamental for less developed capitalist economies to reducing the gap between them and the core capitalist countries.

In this paper, a brief review of the different analytical perspectives used by economic schools throughout history to analyse the topic of technology is made. The relevance of technological changes had different levels of importance at different historical moments. The ideas of the classical economists (Smith, Ricardo, etc..), the socialists and Marx, Schumpeter's ideas, the neo-classical school, the Keynesian view and some ideas from Latin America, are considered in this paper.

Keywords: classical economists, Marx, Schumpeter, Keynes, technological change

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I. INTRODUCTION:

The generation of knowledge and technological change and their relationship with economic issues has always been present in the works of economists. The evolution of economic ideas about technology has always taken into account the fact that economic growth is strongly correlated with the application of innovations and technological change.

The speed and depth of the technological change, along with the process of economic globalization, require us today more than ever before to reflect on the way economists have interpreted the process of generation, diffusion and adaptation of science, technology and innovation.

What the following sections will present are some of the economists' views on technological change and the relevance they attached to it within different theoretical paradigms.

In other words, the importance of knowledge and technology in different schools of economic thought will be reviewed in a historical perspective. An accurate analysis of the dynamics of current capitalism requires an indispensable understanding of the dynamics of technologies and their economic effects.

For the least developed capitalist economies, innovation is fundamental to

reducing the gap that exists between them and the central capitalist countries. In the present paper, a review of the different perspectives from which the topic of technology was approached throughout history is made. The relevance of the technological changes in each of these theoretical paradigms was very different. The view of economists about technological change, as it can be expected, changed at different historical moments. The explanations were not always satisfactory.

The ideas of the classical economists (Smith, Ricardo, etc.), the socialists and Marx, Schumpeter's ideas, the neo-classical school, and the Keynesian view, are considered.

The article ends with a commentary on contemporary developments. In the last decades of the twentieth century a set of contributions were made, linked to evolutionary theories that, with a "neo-Schumpeterian" perspective, have highlighted the evolutionary nature of technological progress.

From the perspective of the reality in the Latin American economies and in relation to these developments, the economists of ECLAC (Economic Commission for Latin America) have made important contributions. Technical progress emerges as a key variable of growth, and development policies require measures to support the generation and diffusion of new technologies.

II. THE CLASSICAL SCHOOL:

The importance of technology has been present since the first publications with economic considerations, but the classical economists were the first to highlight the role of technology in the evolution of the economic system.

From Adam Smith to John S. Mill, all members of the classical school considered the impact of technology and machinery on labour productivity. Since the labour theory of value (obviously with variants) was accepted by almost all of them as an explanation of the exchange value of commodities, the analysis of labour productivity was of fundamental importance.

Adam Smith found in labour the main reason for the wealth of nations[1] and the division of labour was the cause of the increase in productivity[2]. To explain the reasons why the division of labour increased productivity, he considered *"three different circumstances"*. The third one refers specifically to the incorporation of machinery:

"This great increase of the quantity of work which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances; first to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and reduce labour, and enable one man to do the work of many".[3]

Therefore, machinery is considered to be a very important factor in explaining the increase in the productive capacities of the economy. Although Smith could not fully appreciate the process that revolutionized the industry, he was aware of the importance of machinery with regard to explaining increases in labour productivity and therefore was a very important factor in the "wealth of

[1] Smith (1776) [1904] Volume One. Introduction and Plan of the Work. I.I.1 : *"The annual labour of every nation is the fund which originally supplies it with all the necessaries and conveniences of life which it annually consumes, and which consist always either in the immediate produce of that labour, or in what is purchased with that produce from other nations.".*

[2] Smith (1776) [1904] Book I, Chapter I. Of the Division of Labour. I.1.1: *"The greatest improvement in the productive powers of labour, and the greater part of the skill, dexterity, and judgment with which it is anywhere directed, or applied, seem to have been the effects of the division of labour".*

[3] Smith, A. (1776) [1904] Book I, Chapter I. Of the Division of Labor. I.1.5 underlined added

nations." Smith believed that the incorporation of machinery is always useful.

David Ricardo, the most analytical thinker of the classical school, also considered with great attention the question of technology and the incorporation of machinery. In the third edition of his *Principles,* he included a new chapter: "On Machinery".[4] Ricardo added chapter 31 to analyze *"the influence of machinery on the interests of the different classes of society"* and his opinions had changed in comparison to those expressed in the first two editions.[5] These changes were basically about his opinion regarding the replacement of men by machinery:

"These were my opinions, and they continue unaltered, as far as regards the landlord and the capitalist; but I am convinced, that the substitution of machinery for human labour, is often very injurious to the interests of the class of labourers".[6]

The replacement of men by machines generated a high unemployment that affected the working classes and explained why the resistance of the workers to machinery was not an irrational behaviour.[7] However, in this chapter, like Smith, Ricardo also emphasizes the fact that the incorporation of machinery brought about an increase in labour productivity and that there were market mechanisms that would eliminate the problem.

"Ever since I first turned my attention to questions of political economy, I have been of opinion, that such an application of machinery to any branch of production, as should have the effect of saving labour, was a general good, accompanied only with that portion of inconvenience which in most cases attends the removal of capital and labour from one employment to another".[8]

Similarly John S. Mill would present the advantages that technological change bring for the economy.

"The third element which determines the productiveness of the labour of a community, is the skill and knowledge therein existing[9]*...One principal department of these improvements consists in the invention and use of tools and machinery ... ".*[10]

Finally, we should note the contribution of Jean B. Say, the leading representative of the French classical school, which assigned the entrepreneur a role of innovator and, therefore, the entrepreneur was seen as a central figure of technological change. In Say (1809) [1855] he discussed the effects of the use of machinery:

"Whenever a new machine, or a new and more expeditious process is substituted in the place of human labour previously in activity, part of the industrious human agents, whose service is thus ingeniously dispensed with, must needs be thrown out of employ. Whence many objections have been raised against the use of machinery, which has been often obstructed by popular violence, and sometimes by the act of authority itself".[11] *"To give any chance of wise conduct in such cases, it is necessary beforehand to acquire a clear notion of the economical effect resulting from the introduction of machinery".*[12]

Say concludes that: *"The ultimate effect is wholly in its favour".*[13]

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[4] Ricardo, D. (1821): Ch.31, On Machinery.

[5] Ricardo introduced important changes between the three editions, but main changes were introduced in the third edition. For an excellent and in-depth comparison of the three editions see: *Works of David Ricardo*, Vol. 1, ed. by Pierro Sraffa with the collaboration of M. H. Dobb, Cambridge: Cambridge University Press, 1951.

[6] Ricardo D. (1821) Chapter 31, (31.3)

[7] In 1817, John Barton had challenged the claim about the always useful character of the incorporation of machinery and open to debate on the issue. Barton (1817).

[8] Ricardo D. (1821) Chapter 31, (31.2)

[9] Mill J. S. (1848) [1909]Book I, Chapter VII, (I.7.9)

[10] Mill J. S. (1848) [1909] Book I, Chapter VII, (I.7.10)

[11] Say J.B. (1803) [1855] Book I, Chapter VII. (I.VII.7)

[12] Say J.B. (1803) [1855] Book I, Chapter VII. (I.VII.8)

[13] Say J.B. (1803) [1855] Book I, Chapter VII. (I.VII.13)

To sum up, generally speaking, the classical school interpreted the question of the incorporation of machinery and technological change from an "optimistic" perspective, emphasizing:

a) the positive impact on labour productivity,
b) the consequences on the increase of wealth,
c) technology, presented as an "exogenous" factor to the model but essential to explaining the evolution of capitalism.

However, the opinions were not uniform and the incorporation of machinery had different judgements. A detail of the debates about the social and economic effects of the replacement of men by machines of the late eighteenth century and in the nineteenth century can be seen in Groenewegen (2002).[14]

III. KARL MARX:

Since the second decade of the nineteenth century, and resulting from different ideological trends (romantic, nationalist, historicist and socialist), opinions that attempted to demonstrate the limitations of the classical approach emerged, although none of them ended with the hegemony of the classical school and only Marx transcended his time.

Many non-Marxist socialist thinkers of the nineteenth century were initially liberals who agreed with the postulates of the classical school, but became opponents of these theories and questioned the social reality of their time. In relation to the incorporation of new technologies and machinery they were very critical of the consequences they may have for the situation of the working class. The contribution of non-Marxist socialists was more linked to social criticism, and the injustices of capitalism as a system, than to theories that explain economic reality. However, they had an important influence on Marx (particularly the French socialists) and many of their conceptual contributions were among the foundational concepts of that theoretical perspective. It is worth mentioning Jean Charles Léonard De Sismondi (1773-1842) among many others[15]. Sismondi was initially a fervent admirer of liberal ideas (especially Adam Smith), but later reacted strongly against the negative effects of the capitalism of his time. The impossibility of the workers to obtain wage improvements, the poor working conditions and the deterioration of the quality of life of the workers were the main causes of Sismondi's reaction. In 1819 he published *Nouveaux principes d'economie politique*, and claimed that the only thing that "laissez-faire" will achieve is to make the rich even richer and the poor more miserable. He criticized the excess of abstraction of the classical economy, denying the harmony and the coincidence between the individual interest and the collective interest. His concern about economic crises, and the fact that the machinery displaced workers and increased the production without having enough demand, led him to postulate that technological progress should be slowed down to avoid imbalances.

Marx is the most important socialist thinker who assigned significant importance to technology to explain the evolution of the capitalist mode of production. In Marx's vision, man "humanizes" himself by working when he makes the tools that increase the productivity of his work. So, technology is essential to explaining the development of productive forces. In capitalism, according to Marx, the incorporation of better technologies is motivated by the capitalist's intention to

[14] Groenewegen (2002), Part II, Ch. 7. Employment and Machinery. Pages 177-157.

[15] The most outstanding non-Marxist socialist thinkers were, among others: Saint-Simon, Fourier, Owen, and Proudhon (founder of anarchism).

increase the surplus value he appropriates. In his words:

"Like every other increase in the productiveness of labour, machinery is intended to cheapen commodities, and, by shortening that portion of the working-day, in which the labourer works for himself, to lengthen the other portion that he gives, without an equivalent, to the capitalist. In short, it is a means for producing surplus-value".[16]

Machines allow economies of different types:

"... the economies due to progressive improvements of machinery, namely 1) of its substance, such as iron for wood; 2) the cheapening of machinery by the improvement of methods of manufacture, so that the value of the fixed portion of constant capital, while continually increasing with the development of labour on a large scale, does not grow at the same rate; 3) the special improvements enabling the existing machinery to work more cheaply and effectively, for instance, improvements of steam boilers... 4) the reduction of waste through better machinery".[17]

Science and technology occupy a prominent place in the historical evolution of modes of production and in particular in the specific form of capitalist production. Marx considered that industry, through machinery, transformed the functions of the workers and the division of labour within society and transferred masses of capital and workers from one branch of production to another and generated the "industrial reserve army" or "relative surplus population". The generation of relative surplus value through technological change is central in Marx's understanding about the future of capitalism because of its effect on the organic composition of capital and on the rate of profit. In short, technical progress is a necessary condition for the Marxist explanation of the evolution of production modes. Technology allows the development of productive forces which, when in contradiction with social relations, put capitalism in crisis. The fall of capitalism is the result of social conditions but in a context in which technology plays a fundamental role.

IV. NEOCLASICAL REVOLUTION

The last three decades of the nineteenth century witnessed very significant changes in the dominant paradigm of the economy. William S. Jevons with his *Theory of Political Economy*[18], Leon Walras with his *Éléments d'économie politique pure, ou théorie de la richesse sociale*[19] and Carl Menger with the *Principles of Economics*[20] are the names associated with this paradigm change. Alfred Marshall, who was teaching similar ideas in Cambridge, published *Principles of Economics* in 1890.[21]

One of the most relevant ideas of this new paradigm was the rediscovery of the notion of "utility", its integration with a subjective theory of value and the transformation of the political economy into an "allocative theory" ("Economics").[22]

It was a methodological and epistemological change. In the new paradigm, companies have a production function and take decisions (in relation to technology) in conditions of perfect certainty, seeking to maximize their benefits. At the macro level, the neoclassical school postulated the existence of an aggregate production function that is a combination of

[16] Marx, Karl. (1867) [1906]Vol.I,Part IV, Chapter XV (IV.XV.1)

[17] Marx, Karl. (1867) [1906]Vol.III,Part I, Chapter V (I.V.11)

[18] Jevons (1871) [1888]

[19] Walras (1874) [2014

[20] Menger (1871) [2007]

[21] Marshall (1890) [1920].

[22] This theoretical revolution, despite the Keynesian critique, left its mark on the mainstream of the modern economy. The alleged ideological neutrality of the mainstream has often led many economists to take refuge in an ivory tower without committing to solving the problems of their time. On the subject of the commitment of the economists see Blanco (2017).

capital and labour.[23] Regarding technology, it is assumed that there is an amount of scientific and technological knowledge that is an exogenous data of the model. Under these conditions the companies decide to implement the technique that maximizes their benefits or minimizes their costs.[24]

In the middle of the 20th century, Solow made a significant contribution to the treatment of the topic of technology. His work[25], a critical vision of the Keynesian view of the Harrod-Domar[26] model of economic growth, reopened and brought the technological question up for discussion. His work, contemporary to Swan's ideas[27], was carried out within the framework of the theory of economic growth. The neoclassical model of growth (or the Solow–Swan model) is used even today to analyse problems of economic growth.

Neoclassical works on growth abound and there are many differences between them, but with reference to the technological issue we must mention the shift from models with "technology as an exogenous factor" to models that "endogenize" technology. The development of neoclassical growth models incorporates new criteria of technological change and investments in research and development (R&D).[28]

The neoclassical models, which are part of mainstream economy, are highly criticized and the treatment of technological change is one of the most criticized aspect.[29]

It can be concluded that the analytical objective of this school is to explain the decision process but not to understand in depth how technological changes and innovations are generated.

V. INNOVATION, CREATIVE DESTRUCTION AND THE DYNAMICS OF CAPITALISM:

Joseph Schumpeter pointed out that the dynamics of capitalism and its evolution could not be analysed with models that assumed that technology remained constant. He analysed economic development and postulated that innovation is the main element to understand the evolution of capitalism. Innovation was the reason for its dynamics and is defined as:

"... (1) The introduction of a new good ... or of a new quality of a good. (2) The introduction of a new method of production ... which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially. (3) The opening of a new market ... (4) The conquest of a new source of supply of raw materials or half-manufactured goods ... (5) The carrying out of the new organization of any industry, like the creation of a monopoly position ... or the breaking up of a monopoly position ".[30]

[23] The idea of an aggregate production function has been strongly criticized. The so called "Cambridge Capital Theory Controversy" is not subject of this paper but is very close to technological problems. To see the evolution of this controversy see: Cohen and Harcourt (2003)

[24] The assumption of constant and exogenous technology does not mean that the first neoclassical economists ignored the changing nature of technology and its effects. Jevons, for example, referred to the technological changes in his paper "*The Coal Question. An inquiry concerning the progress of the nation and the probable exhaustion of our coal mines".* In this work he formulated the claim known as the *"Jevons paradox".* The technological paradox of Jevons can be expressed as follows: when technological change improves the efficiency with which a resource is used, it may happen that resource consumption does not decrease because of increasing demand. Cfr. Jevons (1865)[1866].

[25] Solow (1956)

[26] Harrod (1948), Domar (1947).

[27] Swan (1956).

[28] Among others: Romer (1990) and Grossman and Helpman (1991)

[29] These criticisms are numerous, ranging from the attack on the assumption of perfect competition (P. Sraffa, J. Robinson, E. Chamberlain) to the devastating critique by Keynes of neoclassical assumption of "full employment". The assumption of rational and maximizing economic agent was also actively questioned.

[30] Schumpeter (1911) [2004]. Chapter II, P. 66.

The "Schumpeterian entrepreneur" is the agent that introduces innovations into the economic process and the main characteristic of capitalism is the permanent technological change. This movement of creative destruction depends on radical innovations which spread to the entire system of capitalist production. Schumpeterian innovation is a restricted concept of innovation because it refers only to radical changes; as he wrote:

"Therefore, we shall impose a restriction on our concept of innovation and henceforth understand by an innovation a change in some production function which is of the first and not of the second or a still higher order of magnitude. A number of the propositions which will be read in this book are true only of innovation in this restricted sense"[31]

The Schumpeterian entrepreneur outperforms others because he has a technological advantage, which begins to resemble a quasi-monopolistic situation. After a period of time, the new technology is copied by other companies, but there is already an indirect effect on the economy as a whole. Therefore, Schumpeter believes that the existence of monopolies is not a problem; companies that use new technologies explain capitalist dynamics. The Schumpeterian view of technological change is more realistic than the neoclassical one, though it also has its limitations. As mentioned above, Schumpeter only takes account of companies that make radical innovations and the radical changes of technological paradigms. However, economic reality shows that capitalist evolution also includes companies that make "minor changes". In other words, these are the companies that introduce minor improvements and which, by slightly modifying current techniques, increase the quantity produced or improve the quality of the products. This omission was later rectified by neo-Schumpeterian economists.

VI. ENDOGENIZING THE TECHNOLOGICAL CHANGES

Another issue concerning minor changes is related to learning (learning theory). Without abandoning the neoclassical perspective, Arrow (1962) focused his attention on technological change as an endogenous variable of growth theory.

"I would like to suggest here an endogenous theory of the changes in knowledge which underlie inter temporal and international shifts in production functions...The role of experience in increasing productivity has not gone unobserved, though the relation has yet to be absorbed into the main corpus of economic theory".[32]

After the Arrow paper, a lot of work of "learning by doing models" and endogenous growth theories have been developed.[33] However, for many years, most of the "orthodox" theoretical developments considered technological change as an exogenous variable that was reflected as the "unexplained" part of the models. The attempts to endogenize technology also presented difficulties and this dissatisfaction with the explanations finally led to other theoretical views. Currently the most beneficial theoretical developments seem to be "evolutionist", "neo-Schumpeterian" and "institutionalist" approaches. These views were widely disseminated and gained acceptance in Latin America because they contribute, from a historical perspective, schemes of analysis of innovations as an evolutionary process.

The most important works from an evolutionary point of view are the ones of

[31] Schumpeter (1939) p 94.

[32] Arrow (1962). P 155-156. (Underlined added)

[33] A detailed analysis of endogenous growth theory and its models can be seen in: Barro, and Sala-i-Martin (2004).

Nelson and Winter (1982) and Rosenberg (1975). The discussion during the seventies of the last century on whether demand or science was the factor that drove technological change has been gradually replaced by more comprehensive analyses that consider both explanations.

VII. THE TECHNOLOGICAL CHANGE AND LATIN AMERICA

The studies conducted in Latin America, basically of economists from ECLAC (Economic Commission for Latin America), take into consideration not only "economic factors" but also sociological, historical, political and institutional ones.

"A country's ability to participate in Global trade and growth depends on its technological, social and organizational innovation capacity. The hallmark of the new knowledge economy is the centrality of innovation to competitiveness and to the international division of work ... Innovation leads to the creation of new products, processes, sectors and activities, and drives structural change which in turn encourages more innovation. The result is a virtuous cycle of growth that reflects an increasing appreciation for knowledge-based value added." [34]

What is particularly taken account of is the external "environment", the institutional framework and the links with other companies. Technological progress is also conceived of as an internal process to the company. The ability to innovate is linked to internal organizational capacities and the "technological" competition between companies is a very important element in explaining the dynamism of technical changes. Recent research has shown that the innovation capacity of economies in essence depends on a set of synergies, institutional features and learning processes. These elements explain innovation processes better than the conditioned maximization assumptions of traditional theories. In Latin America, many economists agree that innovation is a key element of economic growth and that these economies have specificities that give particular characteristics to the technological behaviour of companies. For this reason, and considering that markets do not guarantee a fluid process of technological progress, it is considered that public policies of incentives for the generation and diffusion of technologies are necessary.

[34] ECLAC (2016). p 5.(Underlined added)

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