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Growth *versus* development from Schumpeter to Georgescu-Roegen¹

by

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Abstract

Since the early 1750's economists have elaborate two approaches in order to deal with economic history: a stage theory and a theory of continuing, quantitative growth. J. Schumpeter argued forcibly in favour of the development approach while N. Georgescu-Roegen endorsed the Schumpeterian distinction and considered the stage theory as sketched in Smith or Marx. He proposed a more radical version of his own, embedded in East European history, distinguishing agrarian economies from industrial ones.

The paper provides an analysis of the views of both authors on evolution by analysing others aspects such as the relationship between the qualitative change and the stationary state, the linkages between the evolution and the question of time, and the implications of the dialectical nature of the economic process from a methodological viewpoint (measurability of change, pattern of economic evolution, lessons from the flow-fund model of production) as well as the two stage theory of Nicholas Georgescu-Roegen.

Keywords: Production process, Development, Exosomatic Evolution, Irreversibility, Innovation, Economic system.

JEL classification: B2, B3, Q5

¹ This paper owes a lot to Alcouffe-Ferrari-Hanusch's communication to N. Georgescu-Roegen Conference, Strasbourg, 1998, (English revised version, Alcouffe-Ferrari-Hanusch (2004)).

Introduction

Karl Marx, Joseph A. Schumpeter, Nicholas Georgescu-Roegen are three prominent authors in economic heterodoxy and their contributions are interrelated despite the time gap between them. Schumpeter was born in 1883, the year Marx died. The two younger authors worked together at Harvard between 1934 and 1936 (Hanusch, 1993). At that time, four editions of Joseph Schumpeter's major work, *Die Theorie der wirtschaftlichen Entwicklung* (The Theory of Economic Development), had already been published and he was attempting to supplement his theory with historical data and statistics. As for N. Georgescu-Roegen, that period might be considered as his final years of learning². J. Schumpeter had already died earlier in the 50s by the time Georgescu-Roegen was no doubt writing his major contributions, and it was not until the last decades of his life that he wrote his defence and illustration of entropy. Nonetheless, it is very clear from many of Georgescu-Roegen's quotations that he was always proud of having been J. Schumpeter's student and often stressed how enormously his own intellectual development was influenced by his latter's ideas.

Looking at the work of these three major economists, it is obvious from the sheer magnitude of the area covered by Marx that Schumpeter and Georgescu-Roegen were inevitably confronted with it. J. Schumpeter's major contributions concern the history of economic thought, the theory of economic development and growth of market economies. Georgescu-Roegen gained recognition for his work on consumer and production theory, on growth modeling and, of course, on his attempts to develop a new approach called bioeconomics.

Up to now, a few debates about their respective position on these topics have occurred (Alcouffe, Ferrari, Hanusch, 1998, Heinzl, 2005). Though, there is a high connection between them: it is for instance the case of the Georgescu-Roegen's bioeconomics which is deeply rooted in Schumpeter's works on development. Between Schumpeter and Georgescu-Roegen, the question of the qualitative change which drives the evolution of the economic process has distinct contents which lead to different approaches: while the one of Schumpeter give rise to a minimalist evolutionary approach in which economic growth is a pre-requisite to economic evolution, the one of Georgescu-Roegen is rejecting growth on the basis that it does not comply with physical constraints (entropy law notably). In particular, there is a gap about the origin of qualitative change between the two authors: as it is mainly lying on the irregular

² P. M. Sweezy was also among Schumpeter's assistants. He prepared not only his papers on the kinked demand curve but he was also gathering documents about Marx (and some Austrian authors as well) (Sweezy, 1942).

occurrence of innovations within the Schumpeter's framework -discontinuities-, it is coming from the entropic nature of the economic process with Georgescu-Roegen – the qualitative change is thus indivisible from the production of waste and the decrease/or depletion of environmental resources of high quality, and from the irreversibility of the economic process in general.

It is quite remarkable that the focus of all three scholars is on economic development – the dialectics of infrastructures and superstructures by Marx, the theory of economic development by Schumpeter and the bioeconomic approach by Georgescu-Roegen. All three, it should be noticed, challenged mainstream theory – Marx, so as emphasise the contradictions that were to arise from the collapse of capitalism, Schumpeter to assert the dynamic disequilibrium feature of economic processes, Georgescu-Roegen to suggest a new relationship between economic activity and the natural environment.

Although all three criticise the mechanistic character of economic theory, their angles of attack were perceptibly different. Marx distinguishes between productive forces and production relations and, in the final analysis, makes class struggle the driving force of evolution. Schumpeter places the emphasis on internal factors, endogenous to the economic sphere, while Georgescu-Roegen stresses the fundamental relations between the existence of mankind and its natural resource endowment.

However, for all three economists, the source of evolution is always found in the sphere of production, but its manifestations differ according to the author. Keeping in mind Marx's footprint in the subsequent works of Schumpeter and Georgescu-Roegen, we propose, first, to examine the specific logic which is followed by each author to explain the economic evolution. In the second section of the paper, we will give attention to the manifestations of evolution and analyse their differences between the three authors. Finally, beyond those differences, some correspondences in their work will be noted, and particularly, the introduction of the irreversibility of time into the economic analysis.

1. Evolution, deep-rooted into the sphere of production

If the two authors give a special emphasis to the sphere of production in explaining economic evolution, they do not have a common vision of what are evolution, its origin and its manifestations. Each of them allows indeed a different place to key variables of the production: the technology, the social organization of the production and the natural environmental. While Schumpeter paid attention to the technological change in relation with the social organization, Georgescu-Roegen focuses on the linkages between technology and the natural environment.

1.1. Schumpeter's dynamic theory of evolution

J. Schumpeter is considered as a pioneer in the area of the economics of technological change. Nevertheless, in his seminal exposition (Schumpeter, 1911), and unaltered in the second edition (as well as in the English and French translations), J. Schumpeter does not give the analysis of technology much consideration. All we find is a number of considerations on the relations between technology and the economy in Chapter 1 that deals with the economic circuit. J. Schumpeter states that “Economic logic prevails over the technological. (...) The economic point of view will not only decide between two different methods of production, but even within any given method will operate upon the coefficients, (...)” (*ibidem*, 14-15)

One might have been expected him to more substantially develop this in Chapter 2 on the “the fundamental phenomenon of economic development”, but here again the respective influences of technology and of economic conditions are treated summarily. In the lengthy footnotes (*ibidem*, 309-311), Schumpeter makes a distinction between his attempt to produce an economic theory of evolution and historical sociology, or economic sociology.. He makes a very careful distinction between the static and the dynamic; in particular in his assessment of Mill quoted below:

“Even this title ‘ Influence of the Progress of Society on Production and Distribution’ expresses how much progress is considered as something non economic, as something rooted in the data that only exercises influences upon production and distribution. In particular his treatment of improvements in the arts of production is strictly static. Improvement according to this traditional view is something which just happens and the effect of which has to be investigated, while we have nothing to say about its occurrence per se. What is thereby passed over is the subject matter of this book or rather the foundation stone of its construction. (p. 60 footnote)”

But in emphasising innovation and its various manifestations as well as the role of the entrepreneur, J. Schumpeter apparently relegated technology to a lesser rank. This, perhaps, is where the criticism he received on his reading of evolution, which “neglects all historical factors of change except one, namely the individuality of the entrepreneur” (*ibidem*, 61 footnote) originated.

Schumpeter sees this criticism as “one of the most annoying misunderstandings that arose of the first edition of this book” (*ibidem*, p. 61 footnote). But in his answer, which is one of the few changes in the second edition compared to the first, he argues that: “The ‘entrepreneur’ is merely the bearer of the *mechanism of change*” (*ibidem*). Notwithstanding, he does not explicitly refer to technology with reference to this mechanism of change.

Still in 1939, there are some considerations about technology (precisely “technological lags”) in the chapter II devoted to equilibrium in the section E the title of which expresses some embarrassments (‘Complications and clarification’). Actually Schumpeter is conscious that equilibrium never exists because of “[...] technological lags which in a world in which disturbances never cease to occur for any considerable length of time, would in themselves suffice to account for the fact that in practice we never observe any but those provisional or short-time equilibria [...]” (Schumpeter, 1939, p. 48). Schumpeter in chapter III explains “How the economic system generates evolution”. Again he insists that the process of evolution is endogenous. It obeys to “internal factors of change”, the most important are changes in the methods of supplying commodities. But as he emphasizes the distinction between invention and innovation, it seems that technological change is only a minor of it (cf. *ibidem*, p. 84) as it is only a special case of innovation³.

Nonetheless, in 1942, Schumpeter clearly stated: “It is therefore quite wrong - and also quite un-Marxian - to say, as so many economists do, that capitalist enterprise was one, and technological progress a second, distinct factor in the observed development of output; they were essentially one and the same thing, or, as we may also put it, the former was the propelling force of the latter.” (Schumpeter 1942, 110) (Conclusion of Chapter 10 *Closed Season*).

Contemporary readings of Schumpeter are less sensitive to his preoccupation with making economic theory advance and recognise that technical change is indeed what Schumpeter was concerned with, notwithstanding the terminology that set him apart from the historical school.

³ Innovation is defined as “doing things differently” (p.84) whereas the term “Economic Evolution” encompasses “the changes in the economic process brought about by innovation together with all their effects, and the response to them by the economic system” (p.86).

Thus, when he explains that: “some changes in economic life cannot be explained by the (static) approach to the circuit, even though they are purely economic”, the example he provides is: “Add successively so many mail coaches as you please, you will never get a railway thereby.” (Schumpeter 1911, 64 note). The aim of the (dynamic) theory of evolution is to investigate the “how such changes occur and what economic phenomena they trigger”.

Schumpeter’s only reference to this endogenisation of technical change that is a specific trait of the capitalist system is be found in Schumpeter in *Capitalism, Socialism and Democracy*. Perhaps Schumpeter's inspiration comes from Sombart who uses the Hegelian terminology when referring to the spirit to of the capitalist system (*Geist*)⁴ mentioned by Schumpeter in *Entwicklung*. But a greater source of inspiration is certainly Marx, to whom Schumpeter also refers to in *Entwicklung*:

“This statement of the problem is more nearly parallel to that of Marx. For according to him there is an internal economic development and no mere adaptation of economic life to changing data. But my structure covers only a small part of his ground (p. 60 note)”

In fact, it was not so until 1942 that he seriously dealt with the Marxian approach, and specifically with its dynamics.

The concepts of static and of dynamic analysis as methods for handling economic phenomena are extremely important for Schumpeter. In his view, a static analysis has very little scope in terms of explaining the emergence of innovations and understanding their irregular distribution over time. Indeed, by analogy with mechanics, the static analysis on which the classical theory is based is a theory of equilibrium. Movements may be reversed and the initial state restored.

Under a static analysis, time is irrelevant since all the variables depend on the same moment in time. Hence, a dynamic analysis is necessary to study a system’s evolution, as well as, by implication, the qualitative direction it takes.

Schumpeter accounts for two types of change. The first one appears within a given, institutional sphere and only involves an adaptation to the economic structures. The origin of this change is a factor coming from the outside of the economic process. Moreover, it can be understood by the static analysis. The second one concerns the economic phenomena which

⁴ W. Sombart 1927 entitled the chapter he devoted to technology in contemporaneous capitalism "Der neue Geist" (The new spirit) and the first sentence highlights his position : Modern technology is the authentic child of the European spirit, revolutionary and Faustian, which engenders contemporaneous culture. (...). Besides it is the twin sister of modern science. ". (Bd. III.1, p.78).

involve a qualitative evolution of the economic process: it does not adapt itself but it is modified in its structures. Such changes have their origin within the economic process.

Fundamentally, in Schumpeter's view, the dynamics of change is rooted in two separate processes: economic growth, when the changes entail only the adjustment of the economy to new data, and, economic development, when the changes disturb the economic structures. In the first case, change may be largely reversible. In contrast, in the second case, it is highly irreversible.

1.2. Georgescu-Roegen's view of Evolution

The discovery in the mid-19th century of the second principle of thermodynamics was a major revolution in physics. Indeed, the entropy law introduces the notion of irreversibility into this area for the first time. In his famous paper published in 1824, Carnot reaches an important result: heat always travels in the same direction and this phenomenon of heat propagation explains the loss of power of heat engines (e.g. their diminishing output). During the process of transformation of heat into work, part of the heat energy is inevitably absorbed by the heat source. Hence, it undergoes a change in state although its quantity is maintained. Only a fraction of the free energy can be converted into work. The other fraction is irreversibly dissipated, degraded. Construed in this way, entropy is a measure of the energy dissipated in an isolated system where there is no exchange of matter or energy with the environment. In such a system, entropy can increase over time (irreversible system) or remains constant (reversible system).

Georgescu-Roegen has provided a major work by introducing the entropy law into the economic analysis and uncovering the irreversible nature of transformations of energy and matter (1971). First of all, the entropy law is an evolutionary law that defines the unique direction that changes take within an isolated thermodynamic system. Georgescu-Roegen defines an evolutionary law as follows:

“An evolutionary law is a proposition that describes an ordinal attribute E of a given system (or entity) and also states that if $E_1 < E_2$ then the observation of E_2 is later in Time than E_1 , and conversely. That is, the attribute E is an evolutionary index of the system in point.” (Georgescu-Roegen, 1971, p.128). He adds: "Still more important is the fact that an ordinal measure of any such E can tell even an "objective" mind (...) the direction in which Time flows. Or to use the eloquent term introduced by Eddington, we can say that E constitutes a "time's arrow"”.

Georgescu-Roegen considers attribute E to be a measure of the evolution of the system in the same way as Carnot considered entropy. The entropy law is indeed an evolutionary law that relates an initial state (birth) to a final state (death), between them various intermediate states are placed.

In an isolated system, energy "evolves" qualitatively: free energy that characterises an ordered state is degraded and inevitably becomes dissipated energy, which characterises a state of disorder. Entropy is thus an indicator, an ordinal "measurement" of the energy dissipated in the system.

“For -a point worthy of unparsimonious emphasis- the Entropy Law imposes neither a definite speed nor a particular pattern on the entropic degradation. All it says is that such a degradation is unavoidable and irrevocable" [quoted in Lozada, 1995, p.32]. ”

The determinist nature of the law is inseparable from irreversibility.

Secondly, the entropy law is a dialectical law. To understand Georgescu-Roegen's epistemological position, we must keep in mind the importance of dialectical concepts in contrast to arithmomorphic concepts. Their opposition can be explained in terms of the property of discrete differentiation on which logic is based. Whereas an arithmomorphic concept is distinct and discrete, a dialectical one is distinct but not in a discrete manner. In Georgescu-Roegen's view, a dialectical concept is one that does not comply with the principle of contradiction in logic.

“We must accept that, in certain instances at least, "B is both A and non-A" is the case". [1971, p.46].

The change that lies at the heart of any evolution is a qualitative notion for which there is no dialectical measurement. Change cannot be apprehended using arithmomorphic laws. A good example of this is the entropy law. As stated by Georgescu-Roegen:

“the material universe (...) continuously undergoes a qualitative change, actually a qualitative degradation of energy” [Georgescu-Roegen, 1971, p.129].

In Georgescu-Roegen's opinion, because the entropy law is an evolutionary law, it is dialectical: it accounts for qualitative changes in space and time. Irreversibility, therefore, pertains to historical time, to the time of the entropy law. "Economic time" exists only in the entropic dimension of historical time. Outside of the latter, it has no physical meaning in his view. Consideration of the historical dimension of time by Georgescu-Roegen leads him to introduce irreversibility into economic analysis. The economic horizon is in this way carried

by the historical horizon. In order to express the idea of evolution, Georgescu-Roegen's work consider the notion of process⁵ as essential because it contains a time dimension. The process of production, isolated by means of an analytical boundary, can be broken down into a sequence of operations that occur in a certain order over time.

In simplified terms, the process of production draws on high quality mineral and energy resources - with low entropy - and changes them into products. But this movement occurs simultaneously with the disposal of valueless - high-entropy - waste into the environment. More specifically, two categories of elements contribute to production: funds and flows. These two concepts are fundamental. The role of funds⁶ is to transform flows that pass through the process. This category is made up of elements such as capital, land and labour. Such elements have a dual quality: they offer services that are limited in time⁷ and they are both inputs and outputs (expressed as physical units). Alongside these funds, flows enter and exit the process of production. These are elements whose quality can vary over time and cannot be both inputs and outputs. Implicit in this approach is the complementarity between funds and flows. As such, the standard formulation of the production function does not satisfactorily capture the actual operation of the production process⁸. The funds and flow dimensions are such that there can be no substitution between the two categories of elements.

The concept of "irreversibility" is fundamental in the analysis of any economic process because it implies considering the qualitative change of elements that contribute to production. The act of production is therefore inherently dialectical. Thus, the qualitative change of any production process at one time can be measured by the entropy variable, which, from a physical perspective, can be assessed by the waste flow rejected into the environment. In his analysis, Georgescu-Roegen distinguishes between two categories of non-reversible processes: irreversible processes and irrevocable processes [Georgescu-Roegen, 1970]. Irrevocability is a case of strong irreversibility. It applies to systems that cannot go through a given state any more than once.

⁵ The "process" concept can be related to the representation of biological, physical and economic phenomena.

⁶ Funds and stocks are two distinct concepts. If the stocks can be modified in time (amount deduced or added), the funds offer services which are, on the one hand, bounded in time and, on the other hand, which are constant. Georgescu-Roegen assumes here the steady state hypothesis.

⁷ Georgescu-Roegen considers that the funds as far as their quality and their quantity in the production process are concerned.

⁸ In some recent work, Kurz and Salvadori (2003) have suggested to apply the Sraffa's theory to the production process.

“The entropic degradation of the universe as conceived by Classical thermodynamics is an irrevocable process: the free energy once transformed into latent energy can never be recuperated.” (1971, p.197)

Finally, Georgescu-Roegen believes that the production process irrevocably degrades the terrestrial low-entropy resources (energy and matter). Its mode of operation translates as a deficit in entropic terms [Georgescu-Roegen, 1971, P. 279]. Economic activity is by nature basically entropic.

2. Two dialectical approaches of the evolution?

The filiation between Schumpeter and Georgescu-Roegen, in spite of the latter's emancipation, is nonetheless perceptible and acknowledged. Hence, in 1911, Schumpeter clearly indicated that he was going to deal with part of Marx's area of investigation. As for Georgescu-Roegen, not only did he take up and extensively rework Marx's model, he also was indebted to Schumpeter, in particular for his understanding of the evolution of the economic process. [Georgescu-Roegen, 1971, p. 136].

Although Schumpeter's and Georgescu-Roegen's interest in Marx, even their kinship with him, comes out very clearly in their dynamic approaches, the role of nature in the production process that is so important to Georgescu-Roegen is very limited in Schumpeter's view, while Georgescu-Roegen strongly criticised Marx in a 1960 article in the *Oxford Economic Papers*, (republished in French translation in 1967). We mean to show that their positions are much closer than is generally thought.

2.1. Changes and the nature of evolution

Georgescu-Roegen sees economic activity as having a very particular feature, e.g. to sustain man's exosomatic evolution. Borrowing Lotka's terminology, this notion of evolution refers to the utilisation of "detachable" organs, not belonging to the body, that are produced from natural resources. Exosomatic evolution stands in contrast to endosomatic evolution, which refers to the biological evolution of the species. The economic process taps into terrestrial low entropy and as such may be seen as the vector whereby environmental entropy increases. Because the economic process is rooted in a biological origin, Georgescu-Roegen proposes a new approach he calls bioeconomics⁹ (Gowdy, Mesner, 1998). Thus construed, the economic process appears to be an extension of endosomatic evolution, as the continuation of

⁹ The notion of “bioeconomics” appears in 1975 for the first time in Georgescu-Roegen's works. See also (Georgescu-Roegen, 1977 and 1978).

biological evolution. This is a fundamental point on which the bioeconomic approach to the economic process hinges.

“The term is intended to make us bear in mind continuously the biological origin of the economic process and thus spotlights the problem of mankind's existence with a limited store of accessible resources, unevenly located and unequally appropriated” (1977, p.361).

Georgescu-Roegen's approach derives from Marshall's analysis whereby the economy is not related to mechanics but rather to biology. Moreover, his bioeconomics is even more firmly rooted in Schumpeter 's works on development (Szenberg, 1992).

One of the fundamental conclusions that derive from Georgescu-Roegen's bioeconomics is the rejection of growth on the basis that it does not comply with the entropy law (Miernyk, 1999). On this point, he is a very specific:

“There is growth when only the production per capita of current types of commodities increases, which naturally implies a growing depletion of equally accessible resources” (1976, p.19)

Under these circumstances, evolution is materialised by the continuous degradation of energy and matter: economic growth inevitably leads to a reduction in the terrestrial low-entropy resources. Accessibility is bounded by the law of entropy.

Georgescu-Roegen's adopts an approach to evolution based on development. Founded on the occurrence of qualitative changes in the economy, development is the paramount dialectical concept. Technical progress, limited by the Carnot output, may in this context contribute to an intangible product which is "the enjoyment of life ", which in Georgescu-Roegen's view is the sole purpose of the economic act. In spite of the rather pessimistic (realistic?) impression he gives, his understanding of technical progress does allow for the possibility of innovations capable of controlling mankind's entropic evolution: these are low-entropy economy innovations and substitution innovations.

Finally, Georgescu-Roegen demonstrates that the only plausible course to follow is negative growth. The stationary state is a “myth” rather than a solution¹⁰:

“Undoubtedly, the current growth must cease, may be reversed. But anyone who believes that he can draw a blueprint for the ecological salvation of the human species does not understand the nature of evolution, or even of history, which is that of permanent struggle in continuously novel forms, not that of a predictable, controllable

¹⁰ At a stationary state, a system can not produce motion and/or work at a constant rate.

physico-chemical process, such as boiling an egg or launching a rocket to the moon” (1976, p.25).

Hence, for Georgescu-Roegen, the economic process that is fuelled by economic growth goes hand-in-hand with an irrevocable degradation of terrestrial low entropy. Only negative growth, can save the world where we live, e.g. a world governed by the entropy law.

Irreversibility, which is seated in the act of production, is the physical foundation of economic evolution. The qualitative change associated with economic evolution provides an understanding of the irreversibility of the economic process. This is a view also found in Schumpeter. However, the two authors’ views of the determinants of economic development as well as their treatment of economic growth do not overlap entirely. Schumpeter’s analytical approach to the economic process, which is more optimistic than Georgescu-Roegen’s, gives rise to a minimalist evolutionary approach in which economic growth is a pre-requisite to economic evolution.

As for Schumpeter, his agenda therefore was to build up a theory of change, of motion, or of evolution able to supply "the explanatory principle" for such change. Compared to the classical theory, he was pursuing two objectives: 1/ to supersede the static analytical framework for economic phenomena by introducing a dynamic analysis and 2/ investigate the economic phenomena that "propel" the economy towards a new state of equilibrium. Thus, his quest may be epitomised in the following questions: how, from a given starting situation, can the economy reach a new state of equilibrium? What changes does the economy undergo during the process that takes it to this new state? What is the principle of evolution for the economy?

In his *Theory of Economic Development*, Schumpeter gives a particular meaning to the concept of economic change. He writes (1934, p.64):

“Development in our sense is a distinct phenomenon, entirely foreign to what may be observed in the circular flow or in the tendency towards equilibrium and which influences them as an external force [...]. It is spontaneous and discontinuous change in the channels of the flow, disturbance of equilibrium, which forever alters and displaces the equilibrium state previously existing.”

“But every alteration or displacement does not fit our definition, it includes only those which first emerge spontaneously out of the economic life, and, then are discontinuous, others can be understood without further elaboration and do not present difficulties.” (Schumpeter, 1935, p.92)

Evolution appears as being foreign to the economic circuit whose major characteristic is to identically reproduce a set of conditions or, at least, of the mechanisms whereby economic agents satisfy their needs. More specifically, in his *History of Economic Analysis*, Schumpeter construes evolution in two ways: (p.287, 1954)

“In the wider sense it comprises all the phenomena that make an economic process non-stationary. In the narrow sense it comprises these phenomena minus those that may be described in terms of continuous variations of rates within an unchanging framework of institutions, tastes, or technological horizons, and will be included in the concept of growth.” (*ibidem*).

Economic evolution is marked by the discontinuity of economic phenomena. Economic evolution can only be explained by breaking away from the steady state framework that characterises the economic circuit. He does indeed explore the changes that occur in the economy and the economic phenomena these generate. He pays special attention to the emergence of novelty, that is ascertained when major innovations materialise in the economy – e.g., discontinuity -, producing a new state of equilibrium. It is striking that economic growth is not something that can characterise evolution because it involves only quantitative changes. While evolution is a qualitative, inherently discontinuous phenomenon, growth is nonetheless its pre-requisite.

Another essential point in his analysis is the shift from one equilibrium state to a new state, which is a characteristic feature of economic evolution. This shift does not become manifest as the adjustment of the economic circuit to new data. The similarity with Marx here is noticeable. According to Marx, looking at the history of mankind through the succession of modes of production brings to light the economic system's evolution over time rather than its adjustment to new data. Evolution cannot be predicted. The stationary state does not explain this discontinuity because it consists in simply reproducing the economic process as is. For there to be evolution, however, there must be innovation - for which discontinuity is essential. Indeed, Schumpeter defines his theory of evolution as “a theory of the displacements of the circular flow” (1935, p. 317 - German edition : 98)

What lies at the heart of the “Schumpeterian” conception of evolution is the notion of discontinuity and its materialisation in the economy in the form of new combinations. Technical progress is eminently revolutionary. The emergence of new combinations at the instigation of the entrepreneur is crucial. These innovations, when applied to the sphere of production, drive economic evolution and give rise to irregularity – indeed, these new

combinations are unevenly distributed over time. As a result, economic development is a discontinuous process involving periods of expansion and of recession, reflecting the existence of business cycles.

Finally, in Schumpeter's view, evolution is materialised in the economy as a whole by the discontinuity of the cycles. That discontinuity arises from the irregular occurrence of innovations that are impelled by entrepreneurs. As such, new combinations are the tangible manifestation of economic evolution.

Considering Schumpeter and Georgescu-Roegen, we see that according to the first, new combinations are implemented at the instigation of entrepreneurs. The latter make an essential contribution in terms of productive efficiency because they enable more effective use of the commodities available to be made. In this way, they contribute to enhancing the productive process. This concern with efficiency is reflected in two types of new combinations: the introduction of a new method of production and the use of a new raw material in the process. These two circumstances may be founded on a new source of energy. In those circumstances, productive innovation brings about higher efficiency in the transformations occurring in the productive process.

Here, Georgescu-Roegen's notion of mankind's exosomatic evolution meets with Schumpeter's economic development. Indeed, technical progress as construed by Georgescu-Roegen and the materialisation of development according to Schumpeter are founded on the implementation of technologies that draw on material and/or energy resources in such a manner that productive efficiency is improved. Schumpeter's entrepreneur and Georgescu-Roegen's process of production are the vectors that enhance the efficiency of transformations.

2.2. Economic evolution and Time's conceptions: beyond differences?

For both Georgescu-Roegen and Schumpeter, to analyse economic development requires the boundaries within which qualitative changes occur to be traced out. Hence, they break down the object of their investigation for analytical purposes. Georgescu-Roegen isolates the production processes by means of the dual - spatial and temporal - boundary, while Schumpeter removes economic evolution from the grasp of historical time. For both authors, what is essential is the sphere of production. Trade, as in Marx, is secondary.

According to Georgescu-Roegen, the entropy law directs the development of the production process. Thus it is the ordinal dimension which is considered. Indeed, cardinality

is based on the total absence of qualitative variation. On this point, Georgescu-Roegen writes [1971, p. 112]:

“Since cardinality is associated with the complete absence of qualitative variation, it represents a sort of natural origin for quality”.

In other words, within this analytical framework, the economic process described by flows and funds is independent of time and its quality is unchanging¹¹. In this case, the process is atemporal.

It is therefore necessary for ordinality and the historical dimension of time to be introduced. Because the entropy law is a temporal law in as much as man's consciousness is fundamental, any change in the economic process is necessary linked to that law. Georgescu-Roegen writes:

“Let $E(T_1)$ and $E(T_2)$ be the entropies of the universe at two different moments in time, T_1 and T_2 respectively; if $E(T_1) < E(T_2)$ then T_2 is later in Time than T_1 - and conversely.” (1971, p.133)

“The full meaning of the law is that the entropy of the universe increases as Time flows through the observer's consciousness. Time derives from the stream of consciousness, not from the change in entropy.”

The time he is referring to here is historical time. The entropy of the universe increases on the scale of humanity because we are conscious of it. Time here is an ordinal variable rather than a cardinal one. Its characteristic feature is that it necessarily undergoes qualitative change.

Georgescu-Roegen distinguishes time "T", the ordinal variable, from time "t", the cardinal variable that represents a time interval (T', T"). This distinction is based upon the break in physics between the paradigm of classical physics - reversibility of pathways expressed by dynamic equations that are invariant in relation to "T" (they depend solely on "t") - and the paradigm of thermodynamics - irreversibility expressed by the fact that the laws are functions of "T". Thus, historical time is made up of the succession of consciousnesses of generations of men. For Georgescu-Roegen [1970, p.70], it contains the historical consciousness of mankind.

The dialectical approach to the production process indicates that the quality of elements that contribute to production is neither identical nor constant. Therefore, it is possible to

¹¹The analytical form of such a production process is the following :

$$Q = F(H,K,L;r,i,w)$$

With: Q, production; H, labor; K, capital, L, land; r, the rate of flow coming from the nature; i, the rate of flow coming from other production processes; w, the flow of wastes. This equation means that the level of output is constant as long as the rate of the different flows remain steady.

achieve a higher level of production if the flow of waste is reduced and /or if the quality of funds improves as productivity increases.

Georgescu-Roegen's analysis in this respect has some major implications: on the one hand, it is impossible to consider the evolution of the production process as being independent, and on the other, environmental entropy must irrevocably increase as a result of depletion/emissions. The economic dynamic, seated in the act of production, is inherently related to the laws of physics. To isolate any process of production by means of an analytical boundary is just formal. In actual fact, because it is rooted in the material environment it cannot be released from the laws of physics¹².

Schumpeter does not consider economic evolution to be independent of historical evolution, but he ends up with a conception that is more removed from historical time. Indeed, the meaning he gives to the word "non-reversibility" is ambiguous. Keeping in mind Georgescu-Roegen's developments, does Schumpeter mean irreversibility or irrevocability? The ambiguity here is related to the dialectical nature of the concept. If we consider his analysis of business cycles, economic evolution does not preclude returning to an initial state after a certain time. Discontinuity, the expression of the dynamics of change, is thus characteristic of the low-level irreversibility of economic development. In other words, he is not talking about irrevocability.

This idea of discontinuity is associated with Schumpeter 's dynamic dimension of time. The time that "carries" the economy is referred to as historical time. Schumpeter introduces irreversibility into his analysis of development. A fundamental dimension of the economic process is what he refers to as "historical time".

“At once, the material of economics fundamentally lies in an unique process through historical time” (1954, p.37)

Time is what carries the sequence of events, the irreversibility of successive moments and the changes that create upheaval in the economy. More specifically, economic evolution as the object of economic history is "a part of universal history" (1935, p.83). It is only for the sake of clarity, that he separates the object of his analysis, economic evolution, from historical time by means of a temporal analytical boundary.

In support of this, Schumpeter could use either of these two scientific paradigms:

¹² But that point is no longer surprising since Georgescu-Roegen considers the entropy law as “the most economic of all the physical laws”! (1971, p.280).

- equivalence of moments of time – e.g. , the reversibility of time, the scientific paradigm of Newtonian dynamics. Under this paradigm, pathways are typically reversible. Energy conservation and reversibility are associated (image of the pendulum).

- non-equivalence of moments of time – e.g., the irreversibility of time, the scientific paradigm of equilibrium – e.g., classical - thermodynamics derived from Carnot's work. Energy conservation and reversibility are unconnected: qualitative change is introduced.

Therefore, Schumpeter takes the irreversibility of time although he is not referring to thermodynamics. When he defines the process of development, he emphasises on its fundamental causes. He wrote (1934, p.64):

“Development in our sense is a distinct phenomena, entirely foreign to what may be observed in the circular flows or in the tendency towards equilibrium. It is spontaneous and discontinuous change in the channels of the flow, disturbance of equilibrium, which forever alters and displaces the equilibrium state previously existing. Our theory of development is nothing but a treatment of this phenomenon and the processes incident to it.”

In this context, it is impossible to consider that two distinct moments of time are equivalent. So, the time's flow is necessarily unidirectional. Static analysis can only explain economic evolution from a quantitative viewpoint because of the continuous nature of changes. As the qualitative analysis of evolution brings about discontinuities, dynamic analysis becomes of a great interest.

Conclusion

Georgescu-Roegen characterises the evolution by the degradation of energy and matter, while Schumpeter consider the occurrence of new combinations or the accumulation of capital being the two major forms in which it materialises in the economy. As for the laws that govern evolution, the two approaches differ: in Georgescu-Roegen's opinion, the relevant law - entropy - is a physical one; for Schumpeter, it is an economic one - competition -. But the final states for the two approaches, e.g. a state in which changes are no longer possible, tend to level out these differences. Georgescu-Roegen's final state of equilibrium is characterised by zero production of entropy. For Schumpeter, competition leads to the dissipation of any gain or profit.

In Georgescu-Roegen's analysis, the economic process irreversibly increases the biosphere's entropy. On this basis, even though the maximum achievable state of entropy cannot be predicted, the final state is sure to be characterised by the entropic death of the

universe. In that equilibrium state, production of entropy is zero. For Schumpeter, when the entrepreneur implements new combinations, the outcome is a gain or profit. Only competition can lead to the abolition of profit in the long term. This new state of equilibrium, it would seem, is the final outcome. Evolution is therefore bounded by the abolition of profit, whereas in Georgescu-Roegen it is physically bounded by the law of entropy.

These economists' attempts to revolutionize mainstream economic theory experienced differing fates. But not one of them was completely successful in achieving that aim, although history is still ongoing and it could be that the two paradigms - evolutionary economics and bioeconomics - may end up by tying in together sufficiently to offer an alternative to mainstream theory or be influential enough to beget a new synthesis. This synthesis or cross-fertilisation could be encouraged by bringing together the relevant tools and models. It is well known that Marx endeavoured to come up with mathematical representations of his dialectical conception of evolution all through his life. Georgescu-Roegen applied his skills to underscoring the radical difference between the analytical approach and the dialectical approach by means of formalised models. Furthermore, although Schumpeter was never able to present a formal model for his theory of evolution, Georgescu-Roegen was well versed in the problems connected with non-linearities and discontinuities that appear to be necessary to represent the dialectical and evolutionary approaches.

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