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“Marx, Schumpeter and Georgescu-Roegen :

Three conceptions of the evolution of economic systems?”

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"Marx, Schumpeter and Georgescu-Roegen :

Three conceptions of the evolution of economic systems?[1]"

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Abstract

The aim of this paper is to discuss three approaches of the evolution of economic systems. If Marx, Schumpeter and Georgescu-Roegen together criticised the mechanistic character of economic theory to learn about evolution, each proposed a particular analysis : Marx makes class struggle the driving force of evolution while Schumpeter's concern is the factor endogenous to the economic sphere, and the one of Georgescu-Roegen is the relationship between economic activity and the natural environment. beyond their differences, there are some correspondences in their works. They have introduced the irreversibility of time and historical time into the economic analysis.

Keywords **:** Natural, Development, Exsosomatic Evolution, Irreversibility, Innovation.

JEL classification : B - Schools of Economic Thought and Methodology, Q - Agricultural and Natural Resource Economics

Introduction

Karl Marx, Joseph A. Schumpeter, Nicholas Georgescu-Roegen - setting these three authors side by side is not intended as just another tribute to heterodoxy in economics. After all, there are many ways of moving away from the orthodox view, each of which may be even further removed from the others than it is from mainstream theory in our discipline. Certainly, between these three authors, there is plenty of scope for argument and no scarcity of contradictions. However, the bonds between their contributions were, we believe, even more profound than the two younger authors were willing to recognise.

[1] This paper was presented at the International Symposium "L'œuvre scientifique de Nicholas Georgescu-Roegen" organized by the Charles Gide's Association at the University of Strasbourg, France, 6-7 November 1998.

We know the time gap that separated the two older authors - Schumpeter, like Keynes, was born in 1883, the year Marx died. The two younger authors had even closer ties. If we look at their biographies, we see that they worked together at Harvard between 1934 and 1936. 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 learning. 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. It is quite remarkable that the focus of all three scholars in this respect 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.

1. - Marx's Reading of Changes in Nature and Economic Development

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.

1.1 - Marx and Natural Resources

Marks's position in relation to nature is generally presented as an extremist form of total humanisation of nature through human labour. According to more recent interpretations of Marx, e.g. Elster's, in his controversy with idealism Marx quite unmistakably ends up by denying the existence of nature so intent is he on underscoring the role of production. In fact, as early as in "The German Ideology", he criticises Feuerbach :

> *"He does not see how the sensuous world around him is, not a thing given direct from all eternity, remaining ever the same, but the product of industry and of the state of society" (MEGA 1, I/5, 32).*

He continues :

"For that matter, nature, the nature that preceded human history, (…) today no longer exists anywhere (except perhaps on a few Australian coral islands of recent origin" (ibidem, 34 ; quoted by J. Elster, pp. 87/8.). And further on insists : " So much is this activity, this unceasing sensuous labour and creation, this production, the basis of the <u>whole</u> sensuous world as it now exists…" (ibidem, 33, underlined by us).

According to this conception, it is only in the most primitive forms in distant historical times that one can make a distinction between man and nature, a distinction that inevitably disappears because of "growth in productivity" (...) (*ibidem*, 33). In fact, things are not as simple as Jon Elster claims, since Marx, as we have shown elsewhere, attempts to apprehend historical movement through a dialectical approach in which negation and, moreover, transcendence (surpassing ?) (in German, *aufhebung* has conflicting meanings such as saving and suppressing[2]) are construed as a recomposition of the original elements rather than just their abolition. Thus, in the *Contribution to the Critique of Political Economy*, Marx no longer portrays the whole sensuous world as made up solely of the outcomes of human activity.

*"It would be wrong to say that labour which produces use-values is the only source of the wealth produced by it, that is of material wealth. Since labour is an activity which adapts material for some purpose or other, it needs material as a prerequisite (…)" (our italics).**(c1850/pol-econ/ch01.htm)***

Similarly, human activity is set in a context that does not do away with natural conditions, including and primarily natural resources.

"The level of the productivity of labour, (…), depends in agriculture and extractive industry also upon unpredictable natural conditions. The same quantity of labour will result in a larger or smaller output of various metals -- depending on the relative abundance of the deposits of these metals in the earth's crust. "

http ://www2.cddc.vt.edu/marxists/archive/marx/works/1850/pol-econ/ch01.htm

One might be tempted to consider these notes that further specify the impact of natural conditions on human activity as being of simply stylistic value or as a concession on Marx's part. In our view, it is an illustration of his method in which transformations, including historical ones, do not entirely erase the mark of origins. Confirmation of this interpretation is to be found in Marx's own description of his method. This is the passage that contains the famous aphorism – " The anatomy of man is a key to the anatomy of the ape." **[http ://www.marxists.org/archive/marx/works/1857-cpe/icpe3.txt]** — which in a sense is just a variation on Hegel's adage at the beginning of The Phenomenology of Spirit : "the Owl of Minerva first takes flight with twilight closing in". However, as far as we know, less attention has been paid to the remarks it contains about the relationships between man and nature. First of all, Marx explains why his method is unorthodox :

"For example, nothing seems more natural than to begin with rent, i.e., with landed property, since it is associated with the earth, the source of all production and all life, and with agriculture, the first form of production in all societies that have attained a measure of stability."

http ://www.marxists.org/archive/marx/works/1857-cpe/icpe3.txt

On the contrary, according to Marx, it is the development of bourgeois society and the domination of capital that provides insight into the role played by landed property. Now, as Marx tells us, in bourgeois society, "Agriculture more and more becomes merely a branch of industry, and is entirely dominated by capital." The idea again here is that development frees mankind from natural constraints whereas : "In all forms where landed property rules, the natural relation still predominant". But should one stop at Marx's following observation : "Capital is the economic power that dominates everything in bourgeois society." No, because as Marx concludes : "After analysing capital and landed property separately, their interconnection must be examined."

[2] Marx / Alcouffe, 1985.

[http ://www.marxists.org/archive/marx/works/1857-cpe/icpe3.txt].

Marx's writings abound with passages that lead to the widespread interpretation that he paid little attention to 'nature'. However, we believe that a closer examination of his method tempers that judgement, although he doubtless failed to go through with that investigation and only sketched out the interconnection between capital and nature (in this instance, landed property is simply the way he refers to nature in the system of private property). The ambiguity in many passages relating to modern agriculture is indicative of a far more complex understanding than Elster's rendering, as disclosed by many passages in book III (Capital). In the chapter devoted to differential rent, Marx reasserts the notion of transformation of nature through his analysis of the relationship between natural fertility and effective fertility :

> *"Fertility, although an objective property of the soil, always implies an economic relation, a relation to the existing chemical and mechanical level of development in agriculture, (…)" Capital, Vol. III* [LAWRENCE & WISHART, London, 1974, p. 651]

Marx places special emphasis on the changes brought about by human activity alongside those attributable to "fertility referred to as natural". Taking his reasoning further, he disputes the law of decreasing returns in agriculture, although he is not far from accepting it in industry. Indeed, he discriminates between the role of technical change in industry that brings about obsolescence of machinery "on the contrary, judiciously treated, soil does not cease improving. Land has the advantage to make new investments yield a profit without to sacrifice old ones".

Capital Vol. III Part VI Transformation of Surplus-Profit into Ground-Rent ; Chapter 46. Building Site Rent. Rent in Mining. Price of Land

However it would be a mistake to see this as an unqualified vindication of modern agriculture. On the contrary, these very same chapters dealing with ground-rent expose the contradictory character of modern agriculture and the danger it entails for natural resources. Thus, after having presented the differences between small-scale agriculture and large scale, capitalist agriculture, he states :

> *"In both forms, exploitation and squandering of the vitality of the soil (…), takes the place of conscious rational cultivation of the soil as eternal communal property, an inalienable condition for the existence and reproduction of a chain of successive generations of the human race." Capital, Vol. III* [LAWRENCE & WISHART, London, 1974, p. 812].

On several occasions in his correspondence with Engels, Marx expresses this view of the contradictory development of agriculture in which the exhaustion of the soil may arise either as a result of technical deficiencies or from excessive exploitation. On the 3 /01/1868, he refers to Liebig's theory of soil exhaustion.

On 25th March **[http ://www2.cddc.vt.edu/marxists/archive/marx/letters/marx-eng/68_03_25.htm**], he develops these thoughts on the basis of data taken from Fraas. The latter contends that : "The first effects of cultivation are useful, later devastating owing to deforestation, etc". Marx personally draws the conclusion that supports his own dialectical conception :

> *"The whole conclusion is that cultivation when it progresses in a primitive way and is not consciously controlled (…), leaves deserts behind it (…)".*

[http ://www2.cddc.vt.edu/marxists/archive/marx/letters/marx-eng/68_03_25.htm]

He was later to develop this idea in a highly critical assessment of capitalist agriculture following on from a warning against the destruction of the land. This is in complete contradiction with the widespread view that Marx was insensitive to the destruction of nature. As such, it deserves to be quoted at length :

> *"It thereby creates conditions which cause an irreparable break in the cohesion of social of social interchange prescribed by the natural laws of life. As a result, the vitality of the soil is squandered, and this prodigality is carried by commerce far beyond the borders of a particular state (Liebig). (…) large landed property undermines labour-power in the last region, where its prime energy seeks refuge and stores up its strength as a reserve fund for the*

regeneration of the vital force of nations – on the land itself. Large-scale industry and large-scale mechanised agriculture work together. If originally distinguished by the fact that the former lays waste and destroys principally labour-power, hence the natural force of human beings, whereas the latter more directly exhausts the natural vitality of the soil, they join hands in the further course of development in that the industrial system in the countryside also enervates the labourers, and industry and commerce on their part supply agriculture with the means for exhausting the soil[3]*." Capital, Vol. III* [LAWRENCE & WISHART, London, 1974, p. 813].

This conception of dialectical progression in the application of science to agriculture provides insight into the passage, albeit very brief, in which Marx celebrates small scale peasants of which he is more often uncompromisingly critical.

"The moral history...concerning agriculture...is that the capitalist system works against a rational agriculture, or that a rational agriculture is incompatible with the capitalist system (although the latter promotes technical improvements in agriculture), and needs either the hand of the small farmer living by his own labor or the control of associated producers."

http ://www.marxists.org/archive/marx/works/1857-gru/g1.htm "Karl Marx's Grundrisse"

This reappraisal was needed to confute the very widespread misconception that Marx was an advocate of mechanisation and intensive use of chemicals in agriculture. To be sure, Marx's belief in the progress of rational agriculture remains intact, but he is careful to note that rational agriculture is incompatible with the capitalist system (although the latter encourages technical development in agriculture). Hence, it requires either the hand of the farmer who derives his livelihood from his own labour, or the control of associated producers. Considering this, we can understand how Serhii Podolinsky, one of the forerunners of ecological economics, was able to find inspiration in Marx. It was enough to elaborate on just two topics that were dear to Marx. First, in his search for a physical standard of measurement applicable to all commodities that could provide an explanation for their exchange relation, Marx had settled for labour. The temptation was, therefore, to go even further and to consider, in an actually very Marxian fashion, labour-power to be just the outcome of the consumption of commodities and extend this standard of measurement to energy, without which there would be no commodities. Secondly, although Podolinsky may not have been acquainted with the passages quoted above, they echo other passages in works by Marx published prior to 1880, which refer to natural forces as conditions of production. There is a perceptible ode to mother nature in one of the above quotations. Here again, one might have been tempted to consider land as an allegory for nature which, technically and in the context, refers more specifically to the sun and to energy[4]. Unfortunately, although we know that Podolinsky had great respect for Marx, the latter's opinion of the former's views is not known[5]. At the very least, it was uncertain since Marx asked Engels for his opinion. The latter's answer was itself ambiguous : on the one hand, he considers the research programme for environmental economics wholly unrealistic : "it is absolutely impossible to try and express economic relations in physical magnitudes". 19/12/1882. Nonetheless, Engels' position is not entirely devoid of environmental considerations. Indeed, he is in disagreement with Podolinsky's efforts to show that human labour can prolong the effective use of the energy received on earth. Instead, he believes that human activity has a wholly negative effect on the energy balance by immoderately tapping into natural reserves.

It seems to us that Podolinsky's works, doubtless unknown to Nicholas Georgescu-Roegen, at least show that there are enough affinities between the environmental agenda and the Marxian agenda to allow the possibility of setting up bridges between the two. We shall now see how the concept of economic evolution affords other opportunities to set up such bridges. Nicholas Georgescu-Roegen's interest in Marx's work on this subject is well known.

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[3] This dialectical approach of the part played by modern agriculture did not escape to Maximilien Rubel who stressed in a long footnote that qui souligne dans une longue note that Marx's warnings and critics apply to the "so-called planned agriculture in the so-called socialist States" (Maximilien Rubel cf. p. 1824)

[4] The three words (land, work and sun) are feminine in German(die Erde, die Arbeit, die Sonne).

[5] On these points, see Martinez Alier 1987 and Patrick Magne 1994.

1.2. Dialectical and Mathematical Methods, and Development of Capitalism

Marx's focus on the transformation of economic systems and specifically on the contradictions of capitalism is common knowledge. Let us therefore concentrate on a number of interpretative problems, in particular, those concerning their mathematical representation. Suffice it to remember how emphatic Marx was in calling for an endogenous approach to evolution :

" It must be kept in mind that the new forces of production and relations of production do not develop out of nothing, nor drop from the sky, nor from the womb of the self-positing Idea ; but from within and in antithesis to the existing development of production and the inherited, traditional relations of property. (http ://www.marxists.org/archive/marx/works/1857/grundrisse/ch05.htm#iii)

It was this particular approach to change or growth that drew Georgescu-Roegen's attention in the article he wrote a on Marx's schema[6]s of extended reproduction in the April 1960 issue of *Econometrica*. When subsequently questioned, he spelled out his conceptions of the dialectical method more fully. It is interesting to see how Georgescu-Roegen presents these elements derived from Marx. He places particular emphasis on the observation that in many Marxian models, a flow's dynamic growth is added to that flow for the very same period in which that growth took place. It is striking that it is precisely in this commentary on the dialectical method used by Marx that Georgescu-Roegen establishes the parallel between economics and entropy that prefigured the bioeconomic paradigm :

> *"Finally, let us observe that the position that a material flow can be the source of its own growth is tantamount to the belief in the existence not only of a perpetual motion but of a perpetual accelerated motion as well. But if a flow cannot be the source of its own growth, one may ask, what is the source of economic growth? The answer to the apparent puzzle is not difficult. Since human economy is not an isolated system, economic growth is the result of a continuous tapping of other stocks : the stocks of natural deposits, of various forms of free energy, and above all of that peculiar energy which is accumulated in the body of living organisms. The economic process consists precisely in this tapping. To be sure, this process grows without any counterbalancing decrease in something else, just as physical entropy grows without any decrease in the total energy of the universe. Only in this sense can we speak of the economic process being Hegelian, e.g. containing the source of its own development. But the material elements involved in the process must obey the universal laws of matter and energy."* (NGR, 1960, p. 231).

In this article, Georgescu-Roegen also investigates the scope of the mathematical method for studying evolution, a question that Schumpeter had left unanswered. The conclusion reached by Georgescu-Roegen concerning Marx is hardly any more optimistic.

> *"Yet, when we come to the problem of its evolution, of its mutation into another form, mathematics proves to be too rigid and hence too simple a tool for handling it. Mathematical proofs of future evolutionary changes in any domain, should therefore be viewed with scepticism, even if unlike those analysed in this paper, they are logically irreproachable."* (p. 243).

Thus, we see there is a very strong convergence between Georgescu-Roegen and Marx in the choice of methods while their divergence concerning the relation to nature is doubtless not as great as Georgescu-Roegen himself thought. This question is worth investigating because the reason Marx's notes relating to nature per se are rather cursory is that in his view technology lies between man and nature. This mediation is characteristically dialectical and should be considered when exploring the position of the third member of the triptych in respect of natural resources and economic change.

[6] It is worth to remark that Georgescu-Roegen focuses on the presentation of the schemes given by P. M. Sweezy with whom he has been in Joseph Schumpter's circle.

2. - Nature, Technology and Evolution According to Schumpeter

In a work focused on evolution in which explanations tend to be endogenised, Schumpeter did not to deal very specifically with the role of nature. One might have reasonably expected the matter to come up in the author's treatment of technology, which is considered to be a pioneering work in the area of the economics of technological change. As it turns out, Schumpeter puts the same focus on the evolution and shares the same expectations with respect to economic progress as already commented on in Marx's work.

2.1 - Innovations, Nature and Technology

More peculiarly, in 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 nature or 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, (...) " (pp. 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 (p. 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" (p. 61 footnote) originated.

Schumpeter sees this criticism as "one of the most annoying misunderstandings that arose of the first edition of this book" (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*" (p. 61 footnote). Notwithstanding, he does not explicitly refer to technology with reference to this mechanism of change.

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." p. 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. 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". (p. 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*)[7] 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.

2.2 - Evolution versus Steady State

Schumpeter's 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?

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.

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 reproduction a set of conditions or, at least, of the mechanisms whereby economic agents satisfy their needs. The circuit can be summarised as being "the circular flow is continuously repeating itself in order to provide the greatest reachable satisfaction of wants in given circumstances." (SCHUMPETER, 1935, p.76)

Thus, economic evolution is unlike the “static” operation of the economic circuit. It is the symmetry of economic operations that makes for the equilibrium of the circuit.

More specifically, in his *History of Economic Analysis,* Schumpeter offers a definition for the concept of development with reference to the stationary state. A stationary state is defined as being "an economic process that goes on at even rates, or more precisely, an economic process which merely

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[7] 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).

reproduces itself" (SCHUMPETER *1954*, p. 964). The stationary state is the equivalent of Marx's simple reproduction. It is also an equilibrium state.

Schumpeter construes evolution in two ways : (p. 287)

"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 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.

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.

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.

2.3 - Dynamics according to Schumpeter and irreversibility of evolution

The concepts of static and of dynamic analysis as methods for handling economic phenomena are extremely important for Schumpeter.

The relationship between variables is referred to as static if those variables all have the same time index. It is referred to as dynamic when at the variables have different time indices. 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.

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

- 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).

- the 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.

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 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. With regard to all these points, it is interesting to see what Georgescu-Roegen's reconstruction of these contributions is.

3 - Georgescu-Roegen's View of Evolution, Irreversibility and Time's arrow

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. Until then, the only reference was to the paradigm of classical dynamics derived a century earlier from Newton's works.

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[8].

3.1 - Georgescu-Roegen and the Entropy Law

Georgescu-Roegen ascribes three essential properties to the entropy law (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 E1 < E2 then the observation of E2 is later in Time than E1, 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).

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 temporal law in as much as man's consciousness is fundamental.

> *"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."* (GEORGESCU-ROEGEN, 1971, p. 133)

[8] An isolated system does not exchange neither matter nor energy with the environment. In such a system, entropy can increase over time (irreversible system) or remains constant (reversible system).

"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.

Finally, 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.

3.2 - The Entropic Foundation of the Economic Process and Economic Evolution

The notion of process[9] is essential in Georgescu-Roegen’s work because it expresses the idea of evolution and contains a time dimension. The process of production, considered in isolation 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.

[9] The “process” concept can be related to the representation of biological, physical and economic phenomena.

More specifically, two categories of elements contribute to production : funds and flows. These two concepts are fundamental. The role of funds[10] 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 time[11] 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 process. 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.

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.

> *"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]

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 entropic.

Furthermore, 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 bioeconomics[12]. Thus construed, the economic process appears to be an extension of endosomatic evolution, as the continuation of 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.

On this subject, Georgescu-Roegen writes :

> *"Inspired by Schumpeter, in my bioeconomics I assimilated the emergence of palpable endosomatic changes with his chain of innovations. Both are essentially unpredictable, not even randomly regulated, a point that exposes the fantasized attempts (...) to equate evolution with an arithmomorphic mechanism "*.[SZENBERG, 1992].

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[10] 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.

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

[12] The notion of "bioeconomics" appears in 1975 for the first time in Georgescu-Roegen's works.

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. 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 solution[13] :

> *" 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 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 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.

4. Three dialectical approach to evolution

The filiation between Marx, Schumpeter and Georgescu-Roegen, in spite of the latters' 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 (see above 2.1). 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]. Let us review the corresponding components in these three authors' works.

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

4.1 Technical Progress and Energy Efficiency

Considering just 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 mineral 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.

4.2 Economic evolution and irreversibility

For both Georgescu-Roegen and Schumpeter, to analyse economic development requires the boundaries within which qualitative changes occur to be the 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 unchanging[14].

In this case, the process is atemporal.

It is therefore necessary for ordinality and the historical dimension of time to be introduced. The dialectical approach to the process indicates that the quality of elements that contribute to production is neither identical nor constant. Therefore, it is possible to 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 depletions/emissions. The economic dynamic, seated in the act of production, is inherently related to the laws of physics. To isolate any

[14]The 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.

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 physics[15].

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.

4.3 Three Views of Evolution

Although for all three economists the nature of evolution is determinist, it takes on different shapes. Its source is always found in the sphere of production, but its manifestations differ according to the author.

Georgescu-Roegen characterises it by the degradation of energy and matter while Marx and Schumpeter gave it a less negative normative dimension. The occurrence of new combinations or the accumulation of capital are the two major forms in which it materialises in the economy.

As for the laws that govern evolution, the three approaches differ : in Georgescu-Roegen's opinion, the relevant law - entropy - is a physical one ; for Schumpeter, it is economic - competition - and for Marx, political - class struggle. But the final states for the three 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, while in Marx, the final equilibrium state is one where social classes have been abolished.

The following table gives a brief overview :

	GEORGESCU-ROEGEN	SCHUMPETER	MARX
Driving force	Production process	Entrepreneur	Bourgeoisie
Manifestations	Energy dissipation	New combinations	Capital accumulation
Law	Entropy	Competition	Class struggle
Nature of law	Physical	Economic	Political
Final state of equilibrium	Zero production of entropy	Zero profits	No class

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.

[15] But that point is no longer surprising since Georgescu-Roegen considers the entropy law as "the most economic of all the physical laws"!

Conclusion

These three 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 that the three paradigms - Marxian economics, 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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