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Schumpeter and Georgescu-Roegen on the Foundations of an Evolutionary Analysis

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Schumpeter and Georgescu-Roegen on the Foundations of an Evolutionary Analysis

Abstract

Qualitative change is widely recognized as a defining feature of evolution. Schumpeter and Georgescu-Roegen put it at the center of their methodological reasoning. I revisit important contributions of these two authors, paying attention to the immediate relationship of the major traits and treated issues between their works. With reference to qualitative change, their joint approach provides answers as to (i) why an evolutionary analysis has to necessarily apply a varied less formal set of methods as compared to modern static and dynamic analysis, (ii) why an evolutionary analysis is a necessary component of economic analysis, and (iii) how it can be seen as complementary to modern statics and dynamics. They argued for methodological pluralism, where the choice of methods shall derive from close observation of the subject matter under scrutiny. Georgescu-Roegen's reasoning shows the necessity of interdisciplinary contributions and the interrelation of economic activity and environmental impact and constraints, putting environmental issues immediately on the evolutionary economics agenda. The paper provides a new ground for evaluating Georgescu-Roegen's own and their joint contribution to modern research.

Keywords: Schumpeter, Georgescu-Roegen, qualitative change, evolution, evolutionary methodology

JEL classifications: B25, B31, B41, O10

Schumpeter et Georgescu-Roegen sur les fondements d'une analyse évolutionnaire

Résumé

Le changement qualitatif est largement reconnu comme l'aspect qui définit la notion d'évolution. Schumpeter et Georgescu-Roegen l'ont mis au centre de leur raisonnement méthodologique. Cet article souligne des contributions importantes de ces deux auteurs en mettant l'accent sur la relation directe entre les traits majeurs et les sujets traités de leurs œuvres. En faisant référence au changement qualitatif, leur approche commune fournit des réponses aux questions suivantes : (i) pourquoi l'analyse évolutionnaire doit-elle nécessairement appliquer un ensemble de méthodes varié et moins formel que les analyses statiques et dynamiques modernes; (ii) pourquoi l'analyse évolutionnaire est-elle une composante nécessaire de l'analyse économique; et (iii) comment l'analyse évolutionnaire peut-elle être considérée comme complémentaire aux analyses statiques et dynamiques modernes ? Les deux auteurs ont argumenté en faveur du pluralisme méthodologique, où le choix des méthodes doit dériver de l'observation étroite du sujet étudié. Le raisonnement de Georgescu-Roegen montre la nécessité de contributions interdisciplinaires et de la corrélation entre l'activité économique et l'impact des contraintes environnementales, mettant ainsi la question de l'environnement au cœur du programme de recherche de l'économie évolutionnaire. L'article donne une nouvelle base pour évaluer la contribution de Georgescu-Roegen et de l'approche commune aux deux auteurs pour les recherches actuelles.

Mots-clefs : Schumpeter, Georgescu-Roegen, changement qualitatif, évolution, méthode évolutionnaire

Classifications JEL : B25, B31, B41, O10

Schumpeter and Georgescu-Roegen on the Foundations of an Evolutionary Analysis

1 Introduction

Schumpeter has been an inspiring source for many areas of economic research, including the economics of innovation, public choice, industrial organization, growth theory, entrepreneurship, modern evolutionary economics, economic sociology, economic methodology, and the history of economic thought (*e.g.*, Aghion and Howitt, 1998; Downs, 1957; Freeman and Soete, 1997; Hanusch and Pyka, 2007a; Hausman, 2008; Nelson and Winter, 2002; Scotchmer, 2004; Swedberg, 2003; Tirole, 1988). His writings have been stimulating by their visionary, ambitious, often pioneering character, but also by unclarified details they left. Interestingly, he has not found many followers who have taken up both his central concern for evolution and his distinct methodological approach. I argue that Nicholas Georgescu-Roegen (1906–1994), who has often been embraced as another original contributor (*e.g.*, Beard and Lozada, 1999; Daly, 1995; Hodgson, 1993; Mayumi, 2001; Mesner and Gowdy, 1999; Samuelson, 1966; Witt, 2008), has been an exception in this regard. Having his most enduring impact in the fields of ecological economics and bioeconomics, his works have been explored much less. Coming from mathematics and statistics, he had studied with Schumpeter in Harvard in the mid-1930s. Fond of his mathematical and analytical skills, Schumpeter intended to write with him a "definitive economic treatise" [Samuelson, 1966]. The project was never realized due to Georgescu-Roegen's return to Romania. However, Georgescu-Roegen [1992, 130] states on Schumpeter's importance for him: "Every single one of his distinctive remarks were seeds that inspired my later works. In this way Schumpeter turned me into an economist – the only true Schumpeterian, I believe." Despite these well-known facts, Georgescu-Roegen has been virtually absent from the literature on Schumpeter, including Shionoya's (1997) comprehensive treatment of his work. Although repeatedly mentioned by Georgescu-Roegen and in the secondary literature (*e.g.*, Beard and Lozada, 1999; Mayumi and Gowdy, 1999; Mirowski, 1992), the two authors' close relationship has not received much attention.[1]

In this paper, I revisit important contributions by Schumpeter and Georgescu-Roegen, paying particular attention to the immediate relationship of major traits and treated issues between their works. I account also for Schumpeter's later and late writings to which Georgescu-Roegen particularly referred. The main finding is that, despite differences between them, together the two authors have provided a distinctive encompassing, general framework for the analysis of economic evolution. By concentration on qualitative change as a core characteristic of any kind of evolution, their joint approach can answer the questions as to

[1] Exceptional crossings between the literatures on the two authors constitute Maneschi [2006] and Alcouffe *et al.* [2004]. They particularly focus on Marx' influence on their thinking.

- why an evolutionary analysis has to necessarily apply a varied set of methods as compared to modern static and dynamic analysis;
- why evolutionary analysis is a necessary component of economic analysis; and
- how it can be seen as complementary to modern statics and dynamics.

Three particular reasons make the joint consideration of the two authors worthwhile. First, Georgescu-Roegen clarified in an original way different issues in Schumpeter's works refining his teacher's reasoning. This includes a scientific foundation for the non-stationary nature of the economic process; the justification of the impossibility of a clear distinction between economic and non-economic aspects in actuality; and exact reasons for the reduced role of mathematical methods in an evolutionary analysis. Second, coming from the Schumpeterian issues, along the lines of their joint approach a new access arises to some of Georgescu-Roegen's often involved and difficult writings. Finally, the arising joint approach may help to better locate on, and connect the two authors' contributions the analysis of economic evolution and an evolutionary analysis to the landscape of modern economic research.
To the two authors' joint approach, four traits stand out as distinctive.

(1) Their considerations refer explicitly to the two levels of subject matter and methods of economic analysis, which leads them to discuss, and generally opens up the discussion to the realism of economic research on *both* of these levels.

(2) Their approach is centered around an own, explicit, general, phenomenological (*i.e.*, not theory-laden) notion of evolution (proposed by Schumpeter and refined by Georgescu-Roegen) which particularly stresses the aspect of qualitative change.

(3) They develop a rationale arguing that this notion is sufficient for an evolutionary analysis to necessarily apply a varied set of methods as compared to modern static and dynamic analyses.

(4) Based on their shared notion of evolution they each discuss the relationship of evolutionary and general economic research, ending with diverging conclusions.

The first point may seem natural. The explicit separate consideration of the two levels of subject matter and method, however, is uncommon in both conventional and evolutionary economics. Schumpeter uses the distinction of stationary and evolutionary economy (on the level of subject matter) to describe where conventional economics finds its valid application, and what big range of phenomena an evolutionary approach is to deal with. He sees the static and the stationary economy mostly as methodological artefacts. He finds, however, the application of the tools of conventional economics on them a useful exercise and necessary starting point for economic analysis. Georgescu-Roegen refers also to the two levels of subject matter and methods. But his aim in his 1971 book *The Entropy Law and the Economics Process* (hereafter *Entropy Law*)

(on the level of subject matter) is to show, based on scientific facts (and not merely on casual observation), that the economy in actuality cannot be stationary. His conclusion for economic analysis then is based on a stance different from Schumpeter's 'instrumentalism' [Shionoya, 1997]. For Georgescu-Roegen analytical tools are only valid if they substantively reflect existing reality. His developing of analytical tools thus always includes a most accurate description of the subject matter to be represented to which he continuously refers. (A good example constitutes his flow-fund model in production theory in chapter 9 of *Entropy Law*.)

Their phenomenological notion of evolution leads Schumpeter and Georgescu-Roegen to a distinct approach to evolutionary theorizing.[2] It begins with the close observation of phenomena, then seeks for suitable methods, and finally begins theorizing starting from the observed phenomena. Concepts used in an evolutionary analysis need to grasp qualitative change substantively. They, hence, have a different methodological status compared to such stylized theoretical concepts as utility or production functions in conventional economics. In particular, as Georgescu-Roegen argues, concepts used in an evolutionary analysis are 'dialectical' in character. That is, they display a certain irreducible fuzziness and tend to overlap in meaning with opposed terms. From this recognition Georgescu-Roegen draws three conclusions: there cannot be a theory of domain-specific evolution which confines itself only to aspects of the same domain (such as Schumpeter's theory of economic development); an evolutionary analysis requires the integration of different methodologies; and to reach a valid evolutionary theory different disciplines have to contribute. Finally, Georgescu-Roegen's analysis on the physical level points to the necessary environmental impact of economic activity, and hence to the centrality of environmental issues also from an evolutionary economics perspective. Their writings ultimately aimed to contribute to the development of a theory of social evolution. However, neither Schumpeter, *nor Georgescu-Roegen* incorporated the developments in evolutionary biology and thermodynamics since the late first half of the twentieth century.

The paper is mostly based on the authors' original works. As to Schumpeter, the evaluation explores moreover more recent advances in the research, including especially Shionoya's most encompassing contributions. As to Georgescu-Roegen, I refer particularly to *Entropy Law*. His bioeconomics is treated only so far as already apparent there.[3]

To develop the argument, I first briefly revisit Schumpeter's encompassing analytical system (Section 2). In order to locate Georgescu-Roegen's contribution within Schumpeter's analytical system, I distinguish a stationary and an evolutionary part in it and define, in contrast to mod-

[2]Witt [2008] places the two authors outside the two main strands of modern evolutionary economics, neo-Schumpeterianism and universal Darwinism. He notes that, like the two main strands, Schumpeter [1912] and "naturalistic" approaches (Veblen, Georgescu-Roegen, Hayek, North) could be classified, respectively, into dualistic and monistic on ontological level, depending on whether economic and biological aspects are treated as belonging to different, disconnected spheres or not. He emphasizes at the same time the potential of the latter approaches for an increased attention to topics such as long-term development, cultural and institutional evolution, production, consumption, and sustainability.

[3]See for further treatments of his bioeconomics, *e.g.*, Beard and Lozada [1999, 40–43, ch. 7], Cleveland and Ruth [1997]; Daly [1995]; Georgescu-Roegen [1975, 1978]; Gowdy and Mesner [1998]; Mayumi [2009] and Mesner and Gowdy [1999].

ern statics and dynamics, what may be considered an evolutionary analysis in Schumpeter's sense. I state three unsettled issues to which Georgescu-Roegen later referred. In Section 3, I explain how Georgescu-Roegen's main argument in *Entropy Law*, according to which, for intrinsic reasons, economics cannot be a theoretical science, constitutes an elaboration on basic Schumpeterian issues. I argue that his twofold evaluation of the entropy law for the economic process, on the physical level and the epistemological level, directly elaborates (respectively) on Schumpeter's two levels of subject matter and method. I show how, in stating this argument, he refines, extends and, with respect to certain aspects, questions Schumpeter's analytical approach. The analysis in Sections 2 and 3 generally refers to Schumpeter's late choice of words. This corresponds to Georgescu-Roegen, but contrasts, for example, to Shionoya [1997]. In Section 4, I discuss how the contributions from these two thinkers can be regarded a joint approach, consider various ways in which their joint contribution may newly inform modern methodological debate, and point to the neglect of the cognition/knowledge layer in their reasoning. Section 5 concludes.

2 Schumpeter's economic methodology revisited

Schumpeter developed in his work an encompassing system of economic analysis.[4] His intention was to integrate into one coherent analytical scheme the concerns and perspectives of a wide range of contemporary economic approaches (as varied as the Austrian school, the German historical school, Walrasian equilibrium economics, Marxian sociology and the then up and coming statistical, or econometric, approach). For this to be possible, he incorporated three particular traits in his thinking:

(i) To develop his approach he reflected distinctly on the subject matter under scrutiny and the methods for its analysis.

(ii) This went together with a pervasive concern for correspondence between decisive features of the nature of the subject matter under consideration and the methods used for its analysis.

(iii) On the level of methods, Schumpeter pursued an instrumentalist stance [Shionoya, 1997], according to which the different methods at the economist's hand constitute analytical tools, to be appropriately applied with respect to the respective subject matter or question under study.

Decisive for the structure of his analytical system was his description of economic analysis as composed of the three research areas of *statics*, *dynamics*, and *economic sociology* (presented

[4] Shionoya [1997] describes, with reference to an article on Schmoller [Schumpeter, 1926], the creation of a 'universal social science' as Schumpeter's overarching goal. *Cf.* Heinzel [2006] for details on the following description of Schumpeter's analytical system and its relationship to Shionoya [1997].

here first in keeping with his early choice of words, following Shionoya, 1997). On the level of subject matter, these areas are meant to study, respectively, the *stationary economy*, *economic development*, and the *economic process* as a part of the larger socio-cultural development. On the level of methods, Schumpeter [1954, ch. 2] identifies, as techniques for analyzing the objects of these three research areas, *theory*, *history*, *statistics*, and *economic sociology* (or institutional analysis). Theory is to be applied in all three areas. In dynamics and economic sociology history is added with, in addition, statistics or institutional analysis, respectively, serving as supplementary methods. Table 1 summarizes this analytical system.

Research area	Subject matter	Methods
statics	stationary economy	theory
dynamics	economic development	theory, history supplemented by statistics
economic sociology	economic process as a part of the larger socio-cultural development	theory, history supplemented by institutional analysis

Table 1: Pattern of Schumpeter's analytical system as explained in the text.

2.1 Positions of evolution and of modern statics and dynamics in Schumpeter's system

Working out the positions of evolution and of modern statics and dynamics in Schumpeter's analytical system prepares the distinction between a stationary and an evolutionary component in the next subsection. The distinction of a stationary and an evolutionary component will help to relate Georgescu-Roegen's contributions to Schumpeter's analytical system. As Schumpeter's notion of evolution crystallized only later, whereas his use of the terms statics and dynamics evolved over his work, first some terminological clarification is necessary.

In the famous passage where he introduces his notion of *creative destruction*, Schumpeter [1950, 82f] describes the evolutionary character of the capitalist process as a consequence of the changing social and natural environment and, more importantly, as a result of the introduction of new elements. He identifies the latter as its main driving force. Creative destruction, which 'incessantly revolutionizes the economic structure *from within*,' constitutes for him 'the essential fact about capitalism.' In *History of Economic Analysis* (1954, p. 34), he speaks more neutrally of the 'historical or 'evolutionary' nature of the economic process.' He defines his notion of evolution as follows:

In the wider sense [evolution] comprises all the phenomena that make an economic process non-stationary. In the narrower sense it comprises these phenomena minus those that maybe 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. [Schumpeter, 1954, 964]

His main point is thus that evolution, or the evolutionary economy, is characterized by the (possible) occurrence of *qualitative* change at any level. His description is always *phenomenological*. Accordingly, this most general theoretical description of evolution, as coming about through the interplay of stationary and evolutionary phenomena (*cf.*, *e.g.*, as quoted above), is not bound up with other theories.

I will now argue that Schumpeter's late notion of evolution is essentially consistent with his early notions of economic development and socio-cultural development; and that qualitative change, *i.e.*, the evolutionary aspect, constitutes the major theoretical issue of both his theory of economic development and his economic sociology. To see this recall his statement of the problem of statics and of the problem of his theory of economic development [Schumpeter, 1934, 4f, 61f], together with some additional remarks from Schumpeter [1912, 489]. He there describes the static economy as one in which all economic processes essentially remain the same year after year, changing, if at all, only in size, hence only quantitatively. By contrast, he views development as breaking out from the static framework by 'altering the data of a static economy' and changing the 'traditional economic course.' He sees the problems of statics being solvable through explaining equilibrium, which can be done through reference to only non-economic factors; and he describes the main task of the theory of economic development as explaining the changes to 'traditional economic course', *i.e.*, as explaining qualitative changes in the economy. Thus, economic development constituted, for him, the domain-specific *evolution* within the economic field. Schumpeter [1912, ch. 7] extends this idea of domain-specific evolution to other social fields, such as politics, culture, science and religion. Socio-cultural development then corresponds to the combination of the various domain-specific evolutions occurring within the different fields, including their mutual interrelationships. In keeping with his theory of economic development, Schumpeter sees the explanation of qualitative change also as the main theoretical issue for economic sociology.

Based on the passages discussed so far it can be seen that, while Schumpeter's statics (in his early use of the term) also referred to the concept of equilibrium, it exceeds the modern conceptualization of statics because of its potential to account for a temporal interpretation. Thus, his early conceptualization of statics covers important parts of both modern statics and modern dynamics. By contrast, dynamics, in his early use of the term, is tantamount to his theory of economic development. It generally *exceeds* modern dynamics, as it focuses on qualitative change.

Schumpeter later adopted the modern terminology (*e.g.*, Schumpeter, 1950, 1954). With respect to the modern terms Schumpeter [1950, 104n] states:

We can use [dynamic theory] in order to analyse the stationary economy, just as an evolving one can be analysed by the means of statics ("comparative statics"). Hence dynamic theory need not take, and as a matter of fact has not taken, any special cognizance of the process of creative destruction which we have taken to be the essence of capitalism. It is no doubt better equipped than is static theory to deal with many questions of mechanism that arise in the analysis of that process. But it is not an analysis of that process itself, and it treats the resulting individual

disturbances of given states and structures just as it treats other disturbances.

It can thus be summarized that evolution, essentially characterized by the occurrence of qualitative change, constitutes the subject matter, and the explanandum, of his theory of economic development and his economic sociology. He proposed that modern statics and dynamics based analysis is particularly suited for analysis of the stationary economy; that (modern) dynamic theory is 'better equipped' than static theory for the analysis of 'many questions of mechanism' with respect to the capitalist process; that a comparative-static approach can take into account aspects of an evolving economy; but that neither approach (modern statics or modern dynamics) is able to fully analyze the 'process itself' with respect to its evolutionary nature.

2.2 Tentative definition of an evolutionary analysis

To describe what could be considered an evolutionary analysis, in Schumpeter's sense, it is useful to first tentatively divide his analytical system, more broadly, into a stationary and an evolutionary part. The *stationary* part shall be defined as that which is concerned with the stationary economy; the *evolutionary* part as that which analyzes the evolutionary economy. This distinction keeps to the general structure and methodological outlook of his system. It exceeds it only in that Schumpeter generally used the terms stationary and evolutionary on the level of subject matter, and not on the level of methods. In terms of the three-area structure of his system (Table 1), statics (in his early use of the term) then corresponds to the stationary part, and the combination of dynamics (in his early use of the term) and economic sociology to the evolutionary part.

As is clear from the above considerations, the combination of modern statics and dynamics does not entirely coincide with the stationary part. Both comparative-analytic and (modern) dynamics approaches may also analyze features or mechanisms of the evolving economy. Accordingly, identifying evolutionary analysis with the evolutionary part of Schumpeter's arguments would result in an overlap with both of these approaches. Therefore, for the further discussion, in analogy to Schumpeter's notions of economic evolution in the wider and the narrower senses, two kinds of evolutionary analysis shall be distinguished, as follows. Evolutionary analysis in the *narrower* sense shall be defined as the relatively open way of substantively analyzing the 'process itself' in the areas of dynamics (in Schumpeter's early use of the term) and economic sociology. By contrast, evolutionary analysis in the *wider* sense shall be defined as an analysis that combines the different approaches to economic analysis contained in Schumpeter's analytical system in a mutually fruitful way, in order to study the evolving economy in an encompassing manner. Hence, evolutionary analysis in the narrower sense, corresponding to the combination of dynamics (in his early use of the term) and economic sociology, is opposed to employing concepts that would fit within the concepts of modern statics and dynamics. It is constituted fully within the evolutionary part of Schumpeter's system. With evolution coming

about through the interplay of stationary and evolutionary phenomena, evolutionary analysis in the wider sense always deals with both categories of factors (static and dynamic, in Schumpeter's early uses of the words). It encompasses thus, in addition to the evolutionary part, also the stationary part of his system.
On the level of methods, as can be seen in Table 1, Schumpeter saw in the evolutionary part (and thus in particular in evolutionary analyses in the narrower sense) a limited role for 'theory,' and thus notably for formal, mathematical theorizing. The additional techniques of history, statistics and institutional analysis are presented there as necessary for substantive accounts of the evolutionary character of the economic process.

2.3 Three unsettled issues

As with many of Schumpeter's works, his analytical system is impressive by its encompassing claim but remains to some extent indeterminate in detail. From the perspective of Georgescu-Roegen's elaborations on Schumpeter's work, three particular issues remain unsettled.

(1) Scientific reasons for non-stationarity of economic process
For Schumpeter's analytical system, the distinction of stationary and evolutionary economy on the level of subject matter is of a particular importance. While he describes the stationary state, as treated in his system, as a 'methodological fiction,' he takes the evolutionary nature of the economic process as a basic ontological fact. His arguments in support of the non-stationarity are mainly based on common-sense observation of everyday business, the economy or economic history (*e.g.*, Schumpeter, 1934, ch. 2, 1939: 36f, 1950: 83). He does not substantiate the omnipresence of qualitative change in the economic process with *scientific* reasons.

(2) Clear distinction between economic and non-economic aspects and its importance
In all three of the research areas that can be distinguished in his system, Schumpeter starts his explanation of their respective analytical issues (equilibrium, economic development, socio-cultural development) with the assumption that, on the level of subject matter, a clear distinction between economic and non-economic phenomena can be made. Thus, in his statics he sees the task of the economist as accomplished if the equilibrium is explained with reference to only non-economic phenomena.

When we succeed in finding a definite causal relation between two phenomena, our problem is solved if the one which plays the "causal" rôle is non-economic. We have then accomplished what we, as economists, are capable of in the case in question, and we must give place to other disciplines. If on the other hand, the causal factor is itself economic in nature, we must confine our explanatory efforts until we ground upon a non-economic bottom. [Schumpeter, 1934, 4f]

The same distinction between economic and non-economic phenomena is at the basis of his ex-

planation of economic development 'from within' the economy. And it is similarly constitutive of the distinction between different fields, which is at the basis of his idea of socio-cultural development (which he placed under the heading of economic sociology). In contradiction to his assumption, Schumpeter [1934, 3] describes the extraction of economic facts out of the social process as the 'artificial act of the classifying hand of the investigator' and admits that a 'fact is never exclusively or purely economic.' No place, however, can be found where he discusses a clear criterion to distinguish between economic and non-economic aspects, or where he addresses the implied weakness of his theoretical approach in view of the lack of the possibility to clearly distinguish between them which he admits himself.

(3) Exact reasons for reduced role of mathematical methods in evolutionary part
As noted above, with respect to methods, Schumpeter saw in the evolutionary part of his system, and particularly in evolutionary analyses in the narrower sense, a smaller overall role for theory, that is, also for formal, mathematical theorizing, than in the stationary part or in modern statics and dynamics. He especially regarded history, statistics, and institutional analysis as appropriate methods for the (substantive) analysis of the evolving economic process. He did, however, not come up with exact reasons for this, nor did he provide a formal justification for the, implied, reduced role of mathematics in these types of analyses.

3 Georgescu-Roegen: refinements, elaborations, and original extensions

I now detail how many contributions in Georgescu-Roegen's later work can be recognized as directly emanating from Schumpeterian 'seeds'. More specifically, I argue that central contributions from Georgescu-Roegen, mostly on methodological level, are best understood as refinements and elaborations but also extensions to Schumpeter's original analytical system.

3.1 Central methodological preoccupation and relationship to Schumpeter

At first sight one striking similarity between Schumpeter's and Georgescu-Roegen's contributions is their common concern for methodological issues.[5] While Schumpeter developed an encompassing analytical system, Georgescu-Roegen dealt with many single, often rather technical points in detail. The insights gained from these detailed investigations informed all of his other contributions. Georgescu-Roegen [1992, 130] describes his methodology as "in spirit Machian" and as mainly concerned with "the valid analytical representations of the relations among facts." From this objective two tasks derive for him. The first is to clarify what the 'fundamental facts' are from which economics starts, with respect to scientific, in particular

[5] Georgescu-Roegen's methodological concern has often been emphasized (*e.g.*, Beard and Lozada, 1999; Daly, 1995; Maneschi and Zamagni, 1997; Mayumi, 1995; Meyer, 1974; Mirowski, 1992; Samuelson, 1966).

physical, and philosophical knowledge. The second is to consider their methods, methodological and theoretical implications for economic analysis. He followed this structure of argument especially in *Entropy Law*, which he saw mainly as a methodological tract [Georgescu-Roegen, 1966, xii]. His main intention in this book was to disprove the possibility of economics as a theoretical science, in the sense that it can completely axiomatize its subject matter in order to directly deduce all relevant conclusions [Georgescu-Roegen, 1971, 322–330]. In this paper, my main contention concerning Georgescu-Roegen's work is to demonstrate that, when viewed with respect to its Schumpeterian 'seeds,' his 1971 book *mainly* constitutes a *study into the nature of the economic process and its methodological implications*. The core of my argument is thus immediately clear. Georgescu-Roegen's (1971) main argument continues exactly along the lines of Schumpeter's methodology, further studying explicitly both the nature of the subject matter of economics and issues on the level of methods, and using the character of that subject matter for major methodological conclusions. The link to Schumpeter occurs not only on semantic level, in the common choice of words, such as "economic process" already in the title. It also extends to the structure of the argument and to the level of content. Especially, Georgescu-Roegen closely elaborates on Schumpeter's notion of evolution, which he takes as the basis for his own argument. Accordingly, the encompassing evaluation of the entropy law for the economic process that he provides in this book is situated at two levels, the physical and the epistemological, as considered in the two following subsections.

3.2 Level of subject matter: the economy as an entropic process

On physical level, Georgescu-Roegen's main intention is to prove that "the economic process is not a mechanical phenomenon" [Georgescu-Roegen, 1971, 139]. For him, this proof comes to the same as to show that qualitative, or evolutionary, change constitutes an omnipresent phenomenon in the economic process. To state his argument he takes thermodynamics, and in particular its second law, the 'entropy law,' as the major reference. His rationale is as follows. According to the second law, the entropy of a system, *i.e.*, that share of its total energy which is 'not useful' anymore, tends to increase in any isolated system.[6] He points out that any increase of entropy is, by definition, related to some kind of qualitative change, notably, roughly speaking, by the transformation of 'useful' into 'not useful' energy. Thus, any entropy-generating, or entropic, process is at a basic physical level fundamentally related to some kind of qualitative change. By implication, the economic process, like all life and life-sustaining processes with respect to any isolated system considered around them, is an *entropic* process.

This statement has two major implications. First, it provides scientific reasons for why the economic process is already, at a basic physical level, fundamentally characterized by qualitative change. Second, it implies that any economic production process necessarily relies upon an

[6] An isolated system does not exchange energy or matter with its environment; 'not useful' means that the energy cannot be transformed into mechanical work any more (Baumgärtner, 2000, ch. 3, Beard and Lozada, 1999, ch. 5).

input of low entropy materials and energy providing natural resources, which have, in sum, a lower specific entropy than the set of all end products of that process. Note that Georgescu-Roegen [1971] does not (as far as I see) provide a proof of the necessary link between qualitative change on the physical and the economic levels. Instead, he pursues his argument in Georgescu-Roegen [1976b, 243][7] by stating that, by virtue of the laws of thermodynamics, all physical structure is finite in time. The first implication, scientific reasons, refines Schumpeter's consideration on the level of subject matter, with respect to the first unsettled issue mentioned above in Subsection 2.3. The second, input of low entropy, provides an important extension which is at the base of Georgescu-Roegen's bioeconomic research (see footnote 3 for treatments of it).[8]

3.3 Level of methods: economic process as a 'dialectical' concept

On the epistemological level, Georgescu-Roegen refers to the entropy law mainly as an illustrating device, to discuss the intricacies of economic analysis in the presence of qualitative change. He identifies the entropy law as the prototype of an 'evolutionary law,' which he defines as a proposition that describes an ordinally measurable variable E_t of a given system, stating that, if $E_{t_1} < E_{t_2}$ (*i.e.*, E_{t_2} follows E_{t_1} in the ordinal pattern of E), then the observation of E_{t_2} is later in time than E_{t_1}, and so also conversely (Beard and Lozada, 1999, 33, Georgescu-Roegen, 1971, 128). In view of an economic analysis, which is meant to substantively deal with qualitative change, Georgescu-Roegen's major concern on the epistemological level is consistent treatment of the relationship between quality and quantity. Georgescu-Roegen ([1964] 1976a, 271) emphasizes that quality always precedes quantity, in the sense that before one can speak of a measure of A relative to B, A and B must be distinguished. In the necessary absence of a measure for A, this cannot but be qualitative.

To state the related general methodological issue, Georgescu-Roegen (1966, 21-24, 1971, 43-47) introduces the distinction between arithmomorphic and 'dialectical' concepts. He calls concepts *arithmomorphic*, if they are discretely distinct. Important examples constitute the real numbers or regular geometric forms. He denotes concepts as '*dialectical*,' if they are not limited by an arithmomorphic boundary but surrounded by penumbras in which their meaning overlaps with that of their opposites.[9] Examples that fall into this category are abundant. To illustrate, Georgescu-Roegen points to a man at a certain age, who may be counted as both young and old, a nation which in a particular historical moment may be described as both a democracy and as a non-democracy. Further examples include phenomena of the mind, such

[7] I thank Andrea Maneschi to have reminded me of this article.

[8] The series of (famous) difficulties his treatment of thermodynamics contains has meanwhile thoroughly been worked through. The difficulties include his rejection of the statistical interpretation of thermodynamics in favor of the classical interpretation and his postulate of a fourth law of thermodynamics. According to the latter in any (materially) closed system the material entropy tends to increase. While true for many real-world processes, it cannot count as a natural law (Beard and Lozada, 1999, ch. 6, Faber *et al.*, 1996, ch. 6).

[9] Georgescu-Roegen adopts the term 'dialectical,' by lack of alternative, from Hegel but continuously emphasizes that his notion is differs from Hegel's (*e.g.*, Georgescu-Roegen, 1971, 42, 337).

as the mind itself, consciousness, trust, intelligence, knowledge, ignorance, concepts such as good, justice, likelihood, want, and in particular the notions of utility and welfare. He points out that 'dialectical' concepts are indispensable in life and that all sciences rely upon them. It is evident at the same time that there are only few actual arithmomorphic concepts. Georgescu-Roegen [1971, ch. 3] proceeds to show that all concepts which relate to qualitative change are necessarily 'dialectical' in character. For, neither qualitative change nor a quality itself can be fully represented by an arithmomorphic scheme. This latter insight applies in particular, by definition, to the concept of *evolution*, and thus, due to its evolutionary character, also to the *economic process*.

3.4 Implications and conclusions for economic analysis

The insight that the economic process cannot be fully represented by an arithmomorphic scheme has implications for economics and economic analysis in general and an evolutionary theorizing in particular, especially with respect to the second and third issues raised in Subsection 2.3 above. First, it completes Georgescu-Roegen's argument for the impossibility of economics as a theoretical science, in his sense. For him, a theoretical science is axiomatic, *i.e.*, it requires the logical filing of all extant knowledge in a particular domain in a way that every known proposition is either contained in its logical foundation or deducible from it [Georgescu-Roegen, 1971, 26, 322]. This assures comprehensibility. It also requires, however, the extant knowledge to be *compressible* into a low number of first propositions. The latter condition cannot be met if the subject matter of a science constitutes a 'dialectical' concept.

The recognition of the economic process as a 'dialectical' entity has immediate implications for Schumpeter's theoretical and analytical approach. First, it gives a systematic reason why, in general, there *cannot* be a clear separation between economic and non-economic aspects [Georgescu-Roegen, 1971, 317]. The same holds for the demarcation of any other social or scientific domain. This clearly calls into question the validity of the precondition of Schumpeter's theoretical explanations of equilibrium, economic development and socio-cultural development (that economic and non-economic aspects can be clearly distinguished) and thus undermines his attempts to explain domain-specific evolution and social evolution as an aggregate of domain-specific development phenomena.[10] Second, this reasoning allows Georgescu-Roegen to substantiate Schumpeter's intuitive determination of the appropriate methods for the substantive analysis of the economic process as evolutionary in both the wider and the narrower senses. The analytical inclusion of qualitative change necessarily implies a reduced role of mathematical and quantitative methods on the one hand, and an increased importance of 'dialectical' approaches, such as the Schumpeterian techniques of history and institutional analysis, on the other. It is therefore clear that an evolutionary analysis in the narrower sense *necessarily* has

[10] As set out in Subsection 2.3, Schumpeter was aware of the problem of the lack of clear separability between economic and non-economic aspects but did not discuss its implications for his theories.

to apply a *varied* and *less formal* set of methods as compared to modern static and dynamic economic analysis. As a consequence, evolutionary research necessarily tends to be more empirical and applied, and relies, to some extent, on insights from other disciplines to explain its core phenomena.

What were Georgescu-Roegen's conclusions for economic analysis? On the level of subject matter, Georgescu-Roegen [1971, 316–322] discusses the boundaries of the economic process and, thus, the scope of economics. He finally refers to Marshall's definition of economics as the "study of mankind in the ordinary business of life." On the level of methods, he judges theory and thus mathematical and quantitative analyses as indispensable for economic analysis. His concern is with their limitations:

> *The usefulness of the analytical models that represent similes of actual processes (divested, however, of any qualitative change) cannot be denied. But what matters most in the case of evolutionary structures is the emergence of novelties, of qualitative changes. For these aspects we have no other solution than that of a dialectical approach, involving in particular structural changes. This means to use words, instead of numbers, for truly qualitative change cannot be represented by an arithmomorphic model.* [Georgescu-Roegen, 1979, 325]

Georgescu-Roegen [1976b] distinguishes three categories of dynamic models. *Mathe-matico-imaginative* models start from 'assumptions without any operational value outside the paper-and-pencil concatenation,' such as, *e.g.*, models that presume complete knowledge about crucial variables at all times. They reveal more interesting results with respect to mathematical structure than with respect to the economic aspect of a problem. He emphasizes their purely didactic service. *Mechanico-descriptive* models reduce the essence of all phenomena to some reversible motion, restricting the description to mechanisms. His examples include the Phillips curve, equilibrium theory and the standard growth models. He judges them as potentially particularly misleading or harmful due to their partial realism. By contrast, *analytico-physiological* approaches submit economic phenomena also to a physiological analysis. Examples include Malthus' theory of population, Quesnay's economic table, Smith's study of the pin factory, Marx' analysis of social evolution and, especially, Schumpeter's theory of economic development. They substantively deal with qualitative change.

Georgescu-Roegen's historical and institutional studies of agrarian economies, bioeconomic analysis and notably his flow-fund model of production all follow this latter path. The development of his flow-fund model in Georgescu-Roegen [1971, chapter 9] constitutes a particularly good example of how to interweave a most accurate description of the subject matter to be represented and the model for its analysis in order to develop such analytical tools.[11] However, as clear as he was in his negative statements and general positive methods reflections and recommendations, he was much less critical with respect to the pitfalls of 'dialectical' approaches, including his bioeconomic analyses, notably as regards normative conclusions drawn from them.

[11] See Heinzel [2001] for a detailed discussion.

4 Discussion

I now discuss complementarities and differences between Georgescu-Roegen's and Schumpeter's methodologies and consider how they can be perceived as a joint approach (Subsection 4.1). I then relate the considerations and findings to the modern discussion, reflecting on the questions: at what level and how their joint contribution might constitute a fruitful reference in modern debates (Subsections 4.2 to 4.4). I finally consider their neglect of the cognition/knowledge layer (Subsection 4.5).

4.1 Comparison to Schumpeter, and Schumpeter's and Georgescu- Roegen's joint approach

In Section 3 I argue that Georgescu-Roegen developed his methodological argument in his later work along the same lines as his teacher Schumpeter. Thus, he also refers to the two levels of subject matter and methods. He builds his own methodical conclusions on top of this foundation, calling for good methodology to be methodology that ensures their close correspondence. His principle question regarding the possibility of economics as a theoretical science complements Schumpeter's methodological reasoning.

In stating his argument he provides, moreover, answers to a number of unsettled issues within Schumpeter's approach (Subsection 2.3). Through his biophysical analysis of the economic process, Georgescu-Roegen attempts to put Schumpeter's introspective claim of the non-stationarity of the economic process on the firm ground of laws of nature. At the same time, this leads him one important step beyond his teacher. The observation that the economic process is subject to the laws of thermodynamics implies not only that the occurrence of qualitative change is *inevitable*. It also means that the economic process necessarily feeds on an input of low entropy, and generates waste. Thus, in contrast to their former peripheral status, according to Georgescu-Roegen's analysis environmental and natural-resource issues are, in fact, intimately and inseparably connected to any economic activity, varying only in importance.

Georgescu-Roegen shared Schumpeter's encompassing vision of the subject matter of economics. On the level of methods, both authors generally appreciated theory, analytical models and quantitative analyses. An important difference between them concerns their attitudes toward the realism of theories. For Georgescu-Roegen there could only be a substantive, *i.e.*, most realistic, theorizing. He did not consider methods as mere instruments. He was, therefore, very critical with regard to the overuse of mathematical and quantitative methods, as well with regard to an equilibrium-oriented approach. It is for this reason that his contributions mainly refer to the *evolutionary* part of Schumpeter's system, as defined in Subsection 2.2. By contrast, Schumpeter – based on his integrative view and instrumentalist stance – saw equilibrium economics and mathematical and quantitative methods as approaches in their own right and as necessary parts of economic analysis. His concern was with the evolutionary issue rather as

another, though particularly significant issue on the economic agenda.
Despite this difference, it makes, in my view, sense to perceive Schumpeter's and Georgescu-Roegen's contributions as a *joint approach*. Georgescu-Roegen's contributions not only follow Schumpeter's separation of subject matter and methods, they can also be clearly located within his analytical system, as I have attempted to show above. Furthermore, they provide substantial refinements on both levels and can be recognized as elaborations or extensions of Schumpeter's work. The two methodologies are centred around a common notion of evolution and both aim particularly at accounting for the evolutionary nature of the economic process. Georgescu-Roegen's more restrictive conclusions on the level of methods derive, in this context, from an alternative methodological stance and are not necessarily implied by the evolutionary issue *per se*.

4.2 Notion of evolution

Comparing the (originally) biological notions of evolution often referred to in modern evolutionary economics with Schumpeter's and Georgescu-Roegen's notion reveals a certain tension. While the former in general aim immediately at explaining evolution, and are thus theory-laden, the latter is phenomenological, *i.e.*, descriptive, and particularly emphasizes the aspect of qualitative change. Qualitative change is present in the variation-selection-retention paradigm both in the basic changes at micro level and in realizing transformations at macro level with the meso level as an intermediary stage. Schumpeter's and Georgescu-Roegen's related methodological arguments approach evolutionary theorizing in a different way from what is generally seen in modern discussions (*e.g.*, Buenstorf, 2006; Dopfer *et al.*, 2004; Foster, 2000; Hanusch and Pyka, 2007b; Hodgson, 2004; Knudsen, 2002; Malerba, 2006; Nelson and Winter, 2002; Witt, 2004, 2008). In contrast to the usual more narrow focus on theorizing, Schumpeter and Georgescu-Roegen first discuss the constitution of the subject matter on the one hand, and method and methodological implications on the other. This leads them to their different way of conceptualizing evolution. It provides for a different strategy to approach evolutionary theorizing. According to their methodology, evolutionary theorizing only comes in as a third step in the analysis and rather tackles at first, step by step, different phenomena which relate to evolution (in their sense). It is to be noted that, of course, Schumpeter did not know the developments in evolutionary biology since the late first half of the twentieth century, and that he was critical with biological analogy in view of what he saw during his lifetime (*e.g.*, Schumpeter, 1950, 83). Georgescu-Roegen saw an analogy between the (later) idea of punctuated equilibrium in biology and Schumpeter's description of revolutionary innovations [Mesner and Gowdy, 1999]. He himself, however, rejected not only the statistical interpretation of thermodynamics, but also did never adopt Prigogine's far-from-equilibrium thermodynamics. It is hard to tell how Schumpeter and Georgescu-Roegen would have integrated these developments in evolutionary biology and physics in their evolutionary theorizing had they known them in today's state of

discussion.

4.3 Methodological implications

On the level of methods, Schumpeter and Georgescu-Roegen specifically pursue the issue of how to deal substantively with qualitative change in economic analysis. On solely methodological grounds they show that the claim to deal substantively with qualitative change is *sufficient* for an evolutionary analysis to require a varied set of methods in contrast to the mostly formal or quantitative methods used in modern statics and dynamics. This rather simple, objective methodological reason for a varied analytical proceeding in evolutionary economics seems often to be overlooked in modern discussions.

Their analysis on the level of methods has, furthermore, implications for the classification of analytical concepts. Such stylized theoretical concepts as utility or production functions, as used in conventional economics, especially have to occupy a certain place within a larger theoretical edifice and are appropriately used only to display a small number of general features of the underlying entity. By contrast, concepts that are meant to substantively deal with qualitative change – such as, in the modern literature, routine, technological paradigm, path dependence, lock-in/lock-out, co-evolution or innovation system – necessarily have to reflect a series of (historically) specific features of the entity under consideration. They have thus a principally different methodological status.

Finally, Georgescu-Roegen's critical result for Schumpeter's theories of economic and socio-cultural development arises from his recognition of evolution as a 'dialectical' concept. It implies more generally that the general theoretical problem of an evolutionary analysis as treated by Schumpeter and Georgescu-Roegen remained unstated within their joint approach. Georgescu-Roegen's criticism also applies to modern contributions which build on Schumpeter's idea of domain-specific evolution (*e.g.*, Witt, 2004).

As a corollary to their recognition of the necessary difference in methods between an evolutionary analysis and modern static and dynamic analyses, Schumpeter and Georgescu-Roegen also reflected on the relationship between evolutionary and general economic analysis, with diverging conclusions. While Schumpeter, based on his integrative and instrumentalist stance, saw the two approaches as both being necessary and as complementary to one and other, Georgescu-Roegen was critical of modern economic analysis because of its alienation from facts. Interestingly, in this respect, modern evolutionary economists tend to be closer to Georgescu-Roegen than to Schumpeter. At the same time, Schumpeter's stance shows that the different approaches to economic analysis need not necessarily be regarded as mutually exclusive alternatives. They might rather be fruitfully combined, if valued in their own right. His system of economic analysis provides a general framework for respective comparisons and evaluations of the evolutionary and general economic approaches. His scheme could similarly be applied, for example, to the relationship between behavioral and mainstream economics.

4.4 The environmental issue

With Schumpeter serving as a most fruitful (single) agenda setter, certain structural particularities and deficiencies in his work have persisted in later research, in particular in modern evolutionary economics. One of them has long been the wide neglect of environmental issues. Georgescu-Roegen showed that there is a similarly close link between economic activity and the natural environment as there is, according to Schumpeter, between capitalism and (economic) evolution. Ecological economists have been stressing that this recognition implies a fundamental change in pre-analytic vision (*e.g.*, Daly, 1995). Whereas previously nature was perceived as a subsystem of the economy, in ecological economics the economy is viewed as a – generally constrained and vulnerable – subsystem of nature. As an outcome of this reasoning the need to consider the environment at the thematic level appears as a natural, and a necessary, extension of the original Schumpeterian themes. From an evolutionary perspective environmental issues have become increasingly addressed only recently (*e.g.*, Baumgärtner *et al.*, 2006; Faber and Proops, 1998; Freeman and Soete, 1997; Kallis and Norgaard, 2010; Lehmann-Waffenschmidt, 2007; Van den Bergh, 2007; Van den Bergh *et al.*, 2007; Weber and Hemmelskamp, 2005). Some of these authors stress the co-evolutionary nature of the development of economy and environment. A number of conceptual papers take up complex systems theory in its application to economic systems (*e.g.*, Foster, 1997, 2000). Raine *et al.* [2006] extend Georgescu-Roegen's approach towards the view that, in addition to the entropy in tendency increasing in all isolated physical systems, all spatially fixed and open systems seek to use energy in an ever more efficient way. Following a systems approach to socio-economic complexity, the complementary role of knowledge to energy in economic evolution can then be seen in finding new solutions to energy transformation problems, which may provide a major stimulus for economic self-organization. In a, in a sense, more Schumpeterian vein, Potts *et al.* [2011] emphasize the dual role of entrepreneurship in environmentally constrained economic systems to both further entropy-generating economic growth and come up with solutions for more environmentally benign production and consumption. In the light of global climate change, the continued need for ecological structural change, and accelerated economic expansion of developing countries the environmental issue is likely to prove as a most persistent subject, also on an evolutionary economics agenda.

4.5 Neglect of cognition/knowledge layer

In line with Schumpeter's and Georgescu-Roegen's respective lack of emphasis, limits of cognition and the organization of knowledge – as stressed among the historic authors, for example, by Smith, Knight, Keynes, or Hayek – have not played an important role in the above considerations.[12] In this wider perspective, economic evolution can be seen as a change, in tendency

[12] I thank the anonymous reviewers for raising this issue and for discussing many of the arguments in this subsection as well as in the Conclusion section. Cf. also Loasby [1999] for a treatment of the issue starting from

an increase, in variety and organized knowledge stimulated especially by the scarcity of human cognitive ability. Schumpeter saw the limits of rationality and was also aware of different kinds of rationality involved in economic analysis, for example of the observed subjects and the researcher (*e.g.*, Schumpeter, 1940; Festré and Garrouste, 2008), as well as the uncertainty associated with entrepreneurial activity. Notable is his recognition that behaviors in a stationary economy are characterized by routine, whereas it is the response to qualitative changes in the evolutionary economy which requires judgment and rational choices. Georgescu-Roegen emphasized the economy of thought associated with axiomatic scientific reasoning and pointed to limits of the possibility to represent and measure certain phenomena. More than Schumpeter, he tended toward a positivistic stance with regard to knowledge, as expressed, for example, by his central reference to scientific facts and his concern for objective measurability of phenomena. However, none of the two assigned a prominent place to the aspect that any event requires the central nervous system and its individual classification patterns to 'make sense' of it, so that differences in beliefs, their formation and coordination may well constitute a major feature of economic life (as noted, for example, by Knight, 1921; Keynes, 1921, 1936, or Hayek, 1952). And none of them treated particularly the problems of the organization and distribution of knowledge in the economy in the way exposed, for example, by Smith [1776], or Hayek [1937, 1945].

In my view, the wide neglect of the cognition/knowledge layer by Schumpeter and Georgescu-Roegen does not affect the validity of the basic traits of their methodological reasoning. Their distinct reflection on the two levels of subject matter and methods and their phenomenological notion of evolution with qualitative change as its core characteristic are open to an extension by this layer. The additional consideration of subjective perceptions would further increase the importance of qualitative aspects and complicate the phenomenon of qualitative change, so that their conclusions for economic analysis derived with respect to the issue of qualitative change hold *a fortiori*. As a consequence, also the implied objection from their claim for a close correspondence of methods used and subject matter against the Friedman [1953] criterion remains intact: if successful prediction of outcomes is the sole basis to judge the validity of a model, irrespective of its empirical appropriateness, then there is no means to predict its limits of application.

5 Conclusion

The joint consideration of major contributions by Schumpeter and Georgescu-Roegen in this paper substantiates the oft-alluded close coherence between their works. Both authors shared a deep concern for methodological issues and had an ultimate interest in social evolution. Both of them put qualitative change at the center of their methodological reasoning. It is central to their phenomenological notion of evolution; the distinctive characteristic of an evolutionary

Schumpeter.

economy as compared to the stationary economy; and constitutes, according to them, the central analytical issue of an evolutionary analysis. Their contributions are so close that they could be considered a joint approach. This joint approach shows evolutionary analysis as a necessary component of economic analysis. Moreover, it sees evolutionary analysis as complementary to modern static and dynamic analysis, either generally (Schumpeter) or only so far as the latter is empirically valid (Georgescu-Roegen). The two authors argued for methodological pluralism, where the choice and judgment of methods shall derive from the close observation of the subject matter under scrutiny. The impossibility to confine evolution to single domains calls for contributions from different disciplines.

Coming from Schumpeter's encompassing system of economic analysis, brought to light only by Shionoya [1997], offers a genuine access to Georgescu-Roegen's reasoning, as I attempt to show. Georgescu-Roegen addressed and resolved various problems or challenges in Schumpeter's work and also pointed to important gaps. Especially, by demonstrating the necessary interrelatedness of economic activity and the natural environment, he pointed to the omnipresence and inevitability of environmental issues and constraints as associated with any economic activity. In various important ways Georgescu-Roegen's work can thus be seen as a continuation of Schumpeter's, following in particular his teacher's central concern for the subject of evolution and for methodology.

Neither of the two authors put a special emphasis on the limitedness of human cognition and, for example, the need for variety and specialization as its implications, or treated particularly the organization and distribution of knowledge in the economy. An evolutionary analysis and theorizing that continues to ignore this cognition/knowledge layer would today barely occur as complete. More recent approaches in evolutionary economics that refer to systems or complexity theory (*e.g.*, Subsection 4.4) fully include the knowledge sphere, but do not attach a particular weight to the scarcity aspect in human cognition or to psychological aspects. These approaches also do not follow Schumpeter's and Georgescu-Roegen's phenomenological description of stationary and evolutionary elements as the starting point of evolutionary theorizing.

The limits of cognitive ability and related topics constitute meanwhile one of the most active research fields in economics (*e.g.*, Bénabou and Tirole, 2003, 2011; Camerer and Ho, 1999; Camerer *et al.*, 2004; Kahneman and Tversky, 2000; Smith, 2003; Tirole, 2009). Often, the exploration of such behavioral aspects has been supported by economic experiments which allow to study most immediately the relationship between behavioral hypotheses and observed actions. Still, the conception of an overarching evolutionary analysis in the wider sense that would give guidance as to how the different analytical components combine towards a general theory of economic and social evolution in the Schumpeter/Georgescu-Roegen sense is not much advanced. Further progress in that direction could feed on various sources. On the one hand, the vast, more or less reasoned empirical account of economic evolution and mechanisms at work (*e.g.*, Freeman and Soete, 1997; Stark, 2009) could be used to describe more systematically the stationary and evolutionary elements and their interplay and, thereby, enrich present theoriz-

ing. On the other hand, the continued (joint) evaluation of past authors, including, for example, Alfred Marshall and his notion of progress (*e.g.*, Metcalfe, 2007a,b; Shionoya and Nishizawa, 2008), in particular in view of Schumpeter's and Georgescu-Roegen's joint approach, could be used to further sharpen the concepts and theoretical elements used in this context.

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