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THE ECONOMIC COMPLEXITY OF INNOVATION AS A CREATIVE RESPONSE[1]

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ABSTRACT. Evolutionary economics has finally recognized the limits of biological analogies and is now able to apply the tools of complexity analysis. A better appreciation of the Schumpeterian legacy can help building better foundations to this new phase of evolutionary economics. The paper uncovers the merits of the essay "The creative response in economic history" published by Joseph Alois Schumpeter in the *Journal of Economic History* in 1947 and forgotten since then. The correct appreciation of this Schumpeterian contribution is important not only to better understand the evolution of Schumpeter's thinking but also to elaborate a more inclusive and robust framework able to integrate the contributions of the Classical School and the Marshallian traditions as well as the tools of historical economics so as to implement the new emerging evolutionary complexity.

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1. INTRODUCTION

Evolutionary economics is finally moving away from the ambiguities and dead ends of the approaches of Darwinistic ascent and using the new framework based upon the notion of complexity (Anderson, Arrow, Pines, 1988; Arthur, Durlauf, Lane, 1997; Lane, Pumain, van der Leeuw, and West, 2009). The new understanding of the economic complexity of technological change as a process shaped and explained by the interactions between the individual agents and the organization and structure of the economic system in turn can benefit from a better command of the history of economic analysis and specifically from the full recovery of the Schumpeterian legacy (Arthur, 2009 and 2010; Fontana, 2010a and b).

The Schumpeterian literature has been quite selective. The 1911 book, *The Theory of Economic Development* and the 1942 *Capitalism Socialism and Democracy* have attracted much attention and actually exhausted it. The Schumpeterian essays have been gradually forgotten. The crucial 1928 essay *The instability of capitalism* has faded away. The essay published in the *Journal of Economic History* "The creative response in economic history" in 1947 received little attention after its publication and has been forgotten since then. According to the Social Science Indicator the essay has received no citation in the time span 1985-2012. The other contributions and mainly the two books by Schumpeter received a total of 2400 citations in the same time interval.

This exclusion impedes the correct appreciation of the evolution of the Schumpeterian analysis of the role of innovation in economic growth and deprives economics of a framework that can accommodate in more inclusive approach the important tools of analysis provided by the Classical School, the new historic economics and the Marshallian traditions that are especially relevant to elaborate and implement the foundations of the economic complexity of technological change.

The rest of the paper highlights the merits of the 1947 essay by Schumpeter and puts it in the context respectively of the interpretation of Schumpeter in section 2. Section 3 shows the relevance of the Schumpeterian legacy to implement the new approach to innovation as an emerging property of an economic system with a more inclusive approach to the contributions of other key traditions to understanding the endogenous process of innovation. The conclusions summarize the main results of the analysis.

2. INNOVATION AS A CREATIVE RESPONSE: THE SCHUMPETERIAN SYNTHESIS

Careful reading of the 1947 contribution enables to articulate the hypothesis that with this essay Schumpeter made a relevant attempt to provide a synthesis of his different contributions. In this view the appreciation of the 1947 contribution enables to discuss the asserted divides and contradictions among his previous contributions.

The 1947 essay presents three crucial arguments: a) the historic character of economic processes; b) the distinction between technical and technological change and adaptive responses and creative ones; c) the role of endogenous externalities, together with entrepreneurship, in sorting the chances that the response to unexpected but endogenous out-of-equilibrium conditions be creative or adaptive. Let us analyze them in turn.

History matters. First economics and historic analysis are strictly complementary and cannot be practiced separately without major and mutual losses. Only the cooperation of economics and historic analysis makes it possible to investigate "the sadly neglected area of economic change" (p.149). Economic processes are definitely characterized by non-ergodic dynamics. Irreversibility is an intrinsic characteristic of economic processes. The introduction of innovations "shapes the whole course of subsequent events and their 'long run' outcome. " The introduction of innovations does not affect only the 'transition' from one state to another "leaving the ultimate outcome to be determined by the initial data.… -but- changes social and economic conditions for good, or, to put it differently, it creates situations from which there no bridge to those situations that might have emerged in its absence." More specifically, it is clear that for Schumpeter economic processes that necessarily consider innovation as an integral and irreducible component, are path dependent as distinct from past dependent. A process is past dependent when its non-ergodic dynamics is defined at the onset. All the characteristics of the dynamics based upon irreversibility cannot be changed along the process. Past dependence differs from path dependence. A process is path dependent when it is indeed shaped and affected by irreversibility. Yet events that take place along the process may affect it so as to change its direction, speed, intensity and in general its characteristics. In all non-ergodic processes history matters. Yet it plays different roles according to the relevance of the initial conditions. A past dependent process is deterministic. A path dependent process in inherently stochastic (David, 2005 and 2007).

Adaptive versus creative responses. The analysis of the role of innovation in the competitive process framed by Schumpeter (1928) had already highlighted the role of the characteristics of the system in shaping the innovative process providing an integrated framework where price strategies and innovative strategies could interact. The 1928 contribution was important because provided an analytical framework that appreciated the role of the innovation as a form of reaction of incumbents. In so doing the 1928 contribution anticipates not only the 1942 book, but also the 1947 essay.

In the 1947 essay there is however a quantum jump. Three new radical elements are being introduced: i) not only changes in product markets matter, but all changes in factor markets as much in the levels of the aggregate demand have a role in pushing firms to try and innovate; ii) their reaction is conditional to the characteristics of the system and iii) the introduction of new technologies alters the fundamentals characteristics of the system itself.

The Schumpeterian homo oeconomicus has not Olympian attributes. Agents may face surprises and unexpected events do take place both in factor and product markets. Unexpected changes in factor markets, seldom considered by Schumpeter in his previous works, do play a major role, next to and together with changes in product markets. Here Schumpeter reduces the emphasis on the changes brought about by market rivalry to the demand of each firm, as the single -often exclusive in his scientific approach- factor of change but also to unexpected changes in the aggregate levels of demand. In all cases -ranging from changes in factor markets, to the position of each firm in product markets and aggregate demand- firm had made plans that no longer match the actual conditions of the markets. The 1947 Schumpeterian agents are not able of long-range planning and not able to foresee all the possible events in the future. When surprises do take place they have two alternative possibilities: an adaptive[2] response and a creative one.

The characteristics of the system work as the basic sorting device. According to the characteristics of the system, hence, either one, the adaptive or the creative response will fail or succeed. The inclusion of the characteristics of the system as a key factor in determining the actual outcome of individual behavior seems a late discovery of Schumpeter and the result of the final effort to bring together in an integrated framework the different threads of his analysis.

The late Schumpeter is much more a system thinker than it is retained by the received tradition according to which Schumpeter highlights the central role of entrepreneurial individuals as the determinant of the innovative process and of the chances of economic growth and change of the system. Systems can succeed or fail to innovate because of their intrinsic characteristics. In turn, systems innovate not only because of the supply of entrepreneurial agents but also because of their structure and architectures.

The adaptive response consists in the textbook technical changes on the existing map of isoquants. Firms adjust to the conditions of the market place changing the levels of outputs and inputs and their combinations. They move on the existing maps either to adjust the factor intensity if changes affect the relative factor costs, or to adjust the output levels, if changes affect the desired levels of output, or both. The outcome of the adaptive response is compatible with standard general equilibrium. The adaptive response is nothing else but the textbook the standard adjustment to exogenous shocks.

[2] Note that Schumpeter uses the notion of adaptive reaction as a form of passive attitude when no changes to the existing technology are possible. In complexity theory adaptive responses qualifies, instead, an active choice that includes the possible introduction of changes to the system by agents who try and adapt to its new characteristics. The rest of the paper uses the notion of adaptation following the Schumpeterian meaning (Miller, Page, 2007).

The inclusion of the adaptive response in the range of possible conducts by firms and possible outcomes at the system level is quite important with respect to the evolution of Schumpeter's economics. The 1947 approach seems to solve the apparent contradiction of the *Theory of Economic Development* (1911/1934) where the first part is devoted to praise Walras and the general equilibrium approach and the second to stress the crucial role of the entrepreneur as an exogenous factor that introduces innovations and brings about the creative destruction. General equilibrium applies, hence the first part of the *Theory of Economic Development* is relevant, when the reaction of firms is adaptive, as opposed to creative.

The creative response consists in the introduction of innovations that change the maps of isoquants. The creative response in possible when two qualifying conditions apply: a) firms are guided by actual entrepreneurs, as opposed to managers, and b) the economic system into which they are embedded provides knowledge externalities. In such specific and highly idiosyncratic conditions positive feedbacks take place, the reaction of firms can be creative and lead to the introduction of innovations.

The notion of innovation as the result of a creative response that is conditional to the characteristics of the system is most important from two different viewpoints. First, innovation is not planned and it is not the result of a routine. Innovation takes place as a special form of reaction to unexpected events. Hence, and consequently innovation is the result of positive feedbacks that take place in the interaction among them and between them and the structure, organization and composition of the system. The response of firms cannot be creative in local contexts that do not provide sufficient access to skills and competence. Innovation is possible only when the system can support the entrepreneurial efforts of the agents caught in out-of-equilibrium conditions by events that s/he was not able to foresee and anticipate correctly, with the provision of knowledge externalities.

Finally, technological and structural changes are intertwined and inseparable within a historic process where the past affects -stochastically as opposed to deterministically- the future steps of the dynamics. The equilibrium conditions before the introduction of innovations differ from the new equilibrium conditions: "Creative response changes social and economic situations for good, or, to put it differently, it creates situations that might have emerged in its absence" (150).

This has many implications. First, the distinction introduced by Milton Friedman (1953) between subjective and objective rationality and the claim that only the latter is relevant in economics as the market would be always able to select firms that made the wrong choices so as to restore equilibrium conditions does not apply any longer. The equilibrium conditions after the introduction of innovations are no longer the same as before. The distribution of agents unable to foresee the future and to make valid long-terms plans has important consequences for economics at least when agents are put in the condition to implement successfully a creative reaction.

Second, the creative response and the consequent introduction of innovation is a consequence of the characteristics of the system, but is also a cause. The introduction of innovations in fact is likely to affect the very conditions that make the creative response possible. It is clear, in other words, that knowledge externalities are indeed external to each firm, but absolutely endogenous to the system. The introduction of a specific innovation, in a specific context and at a specific time, can reinforce the provision of knowledge externalities, as much as deteriorate it. Once again the dynamics of the process is non-ergodic but path dependent as opposed to past dependent. A system can support and assist the creative reaction of agents for a given time stretch until the continuative introduction of additional innovations may engender negative net externalities or simply counterbalance the generation of positive externalities with negative ones. The characteristics of a system are not defined at the onset of the non-ergodic dynamics, but are exposed to contingent events that take place along the process, including the endogenous introduction of innovations.

Third, it is clear that the introduction of innovations is now an endogenous determinant of the unexpected events that alter the factor and product market conditions so as to affect their equilibrium conditions. The notion of innovation as a creative response to unexpected events that push firms out-of-equilibrium conditional to the characteristics of the system sets the motion of a dynamic process. For given and positive characteristics of the system, the creative reaction of a firm and the consequent introduction of an innovation cause the out-of-equilibrium conditions of other firms that may be able to react creatively and engender new out-of-equilibrium conditions of other firms. The latter may be able to react creatively in turn, provided that the characteristics of the system –that are now fully endogenous- are able to keep providing the flow of knowledge externalities that make the creative reaction possible (Antonelli and Scellato, 2013).

The dynamic process put in place by Schumpeter's analysis in the 1947 essay is not only consistent, but actually explicative of the Schumpeterian notion of gales of innovations introduced in *Business Cycles*. The larger is the number of firms that are able to innovate and the larger, deeper and more widespread are the changes in the equilibrium conditions of the system, as long as the architecture of system remains able to support the provision of knowledge externalities. The larger the number of innovative firms and the larger the density of innovative efforts within the system and the larger may be the provision of knowledge externalities. At least until congestion effects display their negative consequence. The very provision of knowledge externalities is itself the endogenous product of the generalized participation of a large number of firms to the collective generation of technological innovations. The gales of innovations are the result of that collective and accelerated effort to react creatively to the generalized out-of-equilibrium conditions of the system.

In special circumstances the introduction of innovations is an element of a self-sustained process of structural change. Each innovation in fact has the twin effect to a) altering the equilibrium conditions of the system, and b) changing the conditions of the system itself with respect to the provision of knowledge externalities. If and when the introduction of an innovation increases the capability of the system to provide access to external knowledge at low costs, the process gets momentum and can take place with amplified intensity. As soon the introduction of the last innovation, however, has negative effects on the overall amount of knowledge externalities, the speed of the dynamics declines and can actually stop.

The 1947 contribution by Schumpeter provides an integrative framework that brings together his different contributions. The notion of creative reaction in fact generalizes and synthetizes the divide between the socalled Schumpeter Mark One and the Schumpeter Mark Two that a large literature has implemented. According to this literature Schumpeter changed his mind radically. While his 1911 contribution considered the key characteristics of the European innovation system based upon the entrepreneurs and the innovative banker, the 1942 contribution reflects the key characteristics of the American innovative system based upon the corporation as a portfolio of activities that include the systematic introduction of new activities made possible by the funding of research and development with the extra-profits earned with the introduction of previous vintages of innovations. According to Freeman Clark and Soete (1982) the articulation between the first and the second Schumpeter could be regarded as a form of complementarity rather than a historic sequence. The 1911 contribution, i.e. Schumpeter Mark One applies to science based industries where scientific entrepreneurs play a central role. Schumpeter Mark Two –derived from the 1942 book- would apply to oligopolistic product markets where rivalry among large corporations is based upon product innovations. The notion of innovation as a creative reaction makes clear that the divide between the two Schumpeters had been already reconciled by Schumpeter himself (Malerba and Orsenigo, 1997).

With his 1947 contribution Schumpeter, in fact, had finally elaborated a single framework where innovation can be considered as the endogenous result of the efforts of entrepreneurs, indeed, but made possible and successful by the characteristics of the system. The careful reading of the 1947 contribution suggests that there is but a single Schumpeter that discovers lately the central role of the characteristics of the system into which firms are embedded to provide an integrated understanding of the innovative process (Langlois, 2007).

The framework elaborated by Schumpeter with his 1947 contribution enables to articulate a plausible economic explanation for understanding the residual –i.e. the portion of increase of output that cannot be explained by the increase of inputs- and hence the increase of total factor productivity that stems from the introduction of innovations and that can be considered a reliable indicator of their economic effects.

In a neoclassical world there is no way to explain why firms would not push the increase of their innovative activities to the point where their marginal product matches their costs. In a traditional evolutionary world firms innovate by chance and no economic rationale applies.

In the 1947 Schumpeterian firms –affected by bounded rationality that limit their capability to assess properly the economic context and procedural rationality that makes decision-making sequential- innovate by reaction to unexpected events when and if the system provide them with the pecuniary knowledge externalities that make knowledge and skills cheaper than in equilibrium conditions. Schumpeterian firms do not make long-terms plans and bounded rationality makes them myopic. As a matter of fact the 1947 Schumpeterian agents are not only myopic but also reluctant to change their routines and their technologies.

The change in the characterization of the relationship between the Schumpeterian homo oeconomicus and innovation is substantial with respect to his previous contributions. The 1911 entrepreneur is guided by animal spirits and is possessed by the prospect to concretize his innovative aims. The 1942 corporation has transformed innovation in a routine: the demise of capitalism and the final victory of socialism will be the consequences.

Neither one satisfies Schumpeter any longer. Now firms are pushed to change by unexpected changes. Only then they will try and innovate. The new Schumpeterian firms make relevant mistakes, are caught in out-of-equilibrium by events that are not able to foresee and only then consider the introduction of innovations a possible solution. Reaction is a typical form of procedural rationality: firms consider opportunities and perspectives only after a sequence of unexpected events has taken place. Their success is conditional to the characteristics of the system that become apparent ex-post. Total factor productivity growth is a surprise, induced by a surprise.

The careful reading of the 1947 contribution suggests that the strong emphasis of the literature on the individualistic foundations of Schumpeter's analysis and the central role of entrepreneurs should be reassessed so as to accommodate the new understanding of the central role of the system. The late Schumpeter is much closer to the notion of innovation as the emerging property of a system, than the scholars of the entrepreneurial animal spirits suggest.

The late Schumpeter provides an integrated framework into which the advances of the new economic of knowledge that recognizes the crucial role of the collective character of knowledge as a participated activity that can succeed only when the tacit competence of a variety of agents is able to complement each other in a collective effort.

3. TOWARDS AN EVOLUTIONARY COMPLEXITY

The retrieval of the Schumpeterian legacy and the careful analysis of its evolution are crucial to strengthen the economic foundations of the new approaches to evolutionary economics that impinge upon the tools of complexity analysis. The early attempts to apply the theory of complexity to economics have shown a weak command of the basic tools of the history of economic analysis. The correct use of important analytical foundations elaborated by Schumpeter, but not implemented by the orthodoxy, is crucial to implement a new evolutionary economics that makes a consistent use of the notion and the tools of complexity analysis to understand the dynamics of economic change (Louca, 2010; Arthur, 2010).

Evolutionary complexity can benefit substantially from the inclusion of these landmarks of the analysis of innovations as an exogenous process. Evolutionary approaches based upon biological analogies never made the attempt to incorporate them. Evolutionary complexity should take advantage of them as much as of the very same results of the biological approaches in the effort to provide a more inclusive and articulated framework that the 1947 Schumpeter contributions makes possible (Rosser, 2009; Robert and Yoguel, 2013).

The analytical platform provided by the essay of Joseph Schumpeter with his forgotten 1947 contribution provides in fact the opportunity to elaborate an evolutionary complexity that integrates in a single framework the approaches elaborated in the literature.

The first and most important inclusion applies to general equilibrium analysis. General equilibrium analysis can be considered a special case that takes place when firms are not able to elaborate a creative response and rely on adaptive responses only. In these circumstances exogenous shocks are absorbed by the system without changes to their fundamentals. General equilibrium applies when the unique combination of entrepreneurial energies and knowledge pecuniary externalities are not appropriate to support the creative reaction (Arthur, 2013).

Evolutionary complexity can accommodate general equilibrium as an extreme solution that takes place in specific and idiosyncratic conditions that impede the introduction of innovations. A continuum of outcomes can be considered, besides the return to previous equilibrium conditions, after an exogenous shock. A system may be able to support creative reactions only in a limited stretch of time: after a first round of innovations introduced in response to an exogenous shock the system is no longer able to feed a sustained process. At the other extreme we find instead the possibility that a self-sustained process takes place along an extended period of time because of the positive feedbacks that sustain the continual introduction of innovations that help increasing the actual generation of new knowledge externalities and the widespread occurrence of creative reactions in the system.

In evolutionary complexity that builds upon the notion of innovation as a creative response, the attributes of economic agents in terms of rationality acquire an objective relevance. Friedman's argument according to which markets are able to sort out agents that failed to make the rational choices with no consequences for general equilibrium conditions are no loner valid: the introduction of innovation changes the fundamentals of the system. Suboptitmal choices have long-lasting consequences. The understanding of the limits to Olympian rationality and the appreciation of bounded and procedural rationality matter to grasp the dynamics of the interactions among agents in the system (Simon, 1969, 1979, 1982).

Social interactions do affect the behavior of agents in the formation of their preferences as consumers, strategies as players in product and factor markets and in shaping their capability to generate new technological knowledge in accessing external knowledge. The frame into which such interactions take place plays a central role (Antonelli and Scellato, 2013).

This new inclusive approach is much needed to escape from the substantial failure of evolutionary approaches that build upon biological analogies to elaborating a satisfactory explanation of the endogenous determinants of the introduction of innovations. The wide literature that impinges upon the contributions by Nelson and Winter (1973 and 1982) does not provide a clue to understanding why do firms innovate. Nelson and Winter suggest that firms change their routines and introduce innovations without a specific cause. Firms learn and occasionally change their routines: it is not clear why do firms feel the need to change them. Changes breed changes along Standard Markov chains that do not allow any possible changes in the speed and direction of the innovative process. The innovative process of the evolutionary approaches that impinge upon biological analogies are deterministic and past dependent. History matters only at the beginning of the process. The occurrence of contingent events along the process bears no weight on its development as all the possible outcomes have been defined at the onset.

The notion of systems of innovation, eventually articulated in its national, regional, industrial dimensions acknowledge the important effects of the context into which the innovative process takes place (Nelson, 1993). The holistic dimension and the role of the system in the innovative process is articulated and analyzed, but it is not allowed to change and to affect in new ways the dynamics of the process. The definition of the system in fact is intrinsically static and exogenous. No analysis is provided to grasp the dynamics of the systems themselves. The hypothesis that the very introduction of innovations may change the characteristics of the system is not retained. The origin itself of the innovation system is left unexplained as much as the possibility of its decline and obsolescence is not considered (Malerba, 2005).

This very same literature has provided a strong and sophisticated framework of analysis to understand the selective diffusion of some innovations with respect to others. Evolutionary approaches of biological ascent assume that diversity of agents and alternative technologies are spontaneously reproduced by the system as the result of automatic process.

This perspective is fully consistent with its biological foundations. Variety is the product of random processes of recombination that take place with no intentionality and no economic background. The biological analysis of the selection of the species that have been randomly generated, however, provides useful hints to understand the characteristics of the processes and the underlying factors by means of which some of the many innovations that have been randomly introduced eventually diffuse through the economic system while others are not adopted. Evolutionary approaches built upon biological analogies have not been able to explain why do agents innovate, but do provide a reliable framework to consider the selective diffusion of some innovations as the result of economic forces (Nelson and Winter, 1973 and 1982).

For the same token the thoughtful uses of the biological mechanisms of the replicator analysis provide important insights about the effects on economic growth of the variety of technologies at each point in time. In so doing they provide a new analytical framework to study the consequences of innovation. They do not provide however any hint about the causes of the very same variety that is able to explain economic growth (Metcalfe, 2007).

Evolutionary approaches that implement the notion of complexity can overcome these limitations and accommodate the achievements of the biological evolutionary approaches into a single framework. The analysis of complexity enables in fact to explain innovation as an emergent property that can take place in special circumstances when a variety of specific conditions apply and the interactions between the agents and characteristics of the system engender positive feedbacks (Antonelli, 2011).

The framework of innovation as a creative response that builds upon the 1947 Schumpeter contribution allows to accommodate and integrate the contributions of the Classical School and of the Marshallian tradition that have never been considered by the evolutionary approaches based upon biological analogies. The core of the 1947 contribution of Schumpeter identifies in fact the mismatches in both factor and product markets – and not only the oligopolistic rivalry in product markets or the exogenous supply of entrepreneurs- combined with entrepreneurial resources and crucial knowledge externalities that qualify the systemic conditions as the determinants of the stochastic and contingent possibility – well distinct from the deterministic approaches stemming from biological analogies- of creative responses and the introduction of innovations. The interplay between the innovative efforts of agents caught in out-of-equilibrium and the characteristics of the system accommodates the central role of positive feedbacks as a consequence of the special circumstances. Finally the introduction of innovations feeds a self-sustained process. It is itself the cause of new mismatches and new positive feedbacks based upon new larger knowledge externalities that last as long as the endogenous conditions of knowledge externalities are improved. The dynamics of the process is non-ergodic, but path dependent (Antonelli, 2011).

This analytical core of evolutionary complexity can include and accommodate into a single and articulated framework not only the achievements of evolutionary approaches based upon biological analogies, but also the crucial contributions of Classical economics that have not found any appropriate use in contemporary studies of technological and structural change. Yet the contributions of the demand pull approach based upon the intuition of Adam Smith eventually elaborated by Allyn Young (1928) and Nicholas Kaldor (1981) about the central relationship between the extent of the market, the levels of the division of labor and hence of specialization and the consequent opportunities for learning and eventually generate new technological knowledge and introduce innovations deserve to be reconsidered and better appreciated. In the Schumpeterian synthesis in fact changes in the aggregate levels of demand matter as much the changes in the individual demand curve of oligopolistic corporations in altering the expected equilibrium conditions. Recent attempts in evolutionary economics to better consider the active role of demand in shaping both structural and technological change contribute this line of analysis (Saviotti and Pyka, 2014)

Along the same lines the analysis of the direction of technological change within the induced technological change approaches elaborated by John Hicks (1932) and Vernon Ruttan (1997) upon the early Marxian intuition can play a role in evolutionary complexity. The hypothesis that technological change is induced by changes in factor markets that push firms to try and change their input combination and at the same time to introduce directed technological changes is perfectly consistent with the Schumpeterian synthesis that firms innovate while trying to react to unexpected changes to the economic conditions upon which their tentative equilibrium solutions had been built (Antonelli, 2008).

The Marshallian tradition also can provide important complementary inputs to evolutionary complexity. The composition of the system in terms of the variety and relative weight of the different activities plays a central role in this context. There systems endowed with a good composition and systems that see their high quality composition deteriorating as a consequence of the entry of new agents and/or exit of others from activities that provided the rest of the system with complementary inputs. The Marshallian notion of Jacobs externalities finds here a new and increasing scope of application (Hildago and Hausmann, 2009).

Evolutionary approaches that apply the tools of complexity can take advantage of the new developments of knowledge as an economic activity that is sharply characterized by the intrinsic complementarity of the competence and the knowledge stock of individual organizations. The generation of new knowledge is more and more viewed as the collective result of the recombinant integration of different kinds of knowledge as inputs. No new knowledge can be generated by each individual without the access and use of knowledge generated by third parties. The dual identity of knowledge as an output and yet an input expands the original notion of knowledge indivisibility, into the new appreciation of the crucial role of knowledge cumulability, complementarity and non-exhaustibility into knowledge that is now viewed as an activity rather than a good. External knowledge is an essential input into the generation of new knowledge. The access conditions to it are determined by the organization, composition of activities that take place within each system and by the quality of market transactions and the availability of qualified and fertile interactions (Antonelli, 2008 and 2013).

The understanding of the causes and the dynamics of the emergence, development and eventual decline of national, regional and industrial systems of innovation becomes a central issue. The Marshallian analysis of endogenous externalities that are formed and shaped by the changing structure of the system, the evolution of interaction networks, the flows of intersectoral and interfirm transactions becomes essential component of evolutionary complexity (Metcalfe, 2010; Antonelli and Ferraris, 2012 and 2013).

In the evolutionary approaches that apply the tools of complexity analysis building upon the correct appreciation of the Schumpeterian legacy the understanding of the historic character of economic change finds much a stronger foundation and a broader scope of application. The process of economic change is in fact better understood as a path dependent non-ergodic dynamics where history matters and yet the changing conditions into which the dynamics displays its process affect it changing speed, direction and its very survival (Blume and Durlauf, 2006).

Path dependence is intrinsic to evolutionary complexity because the interplay between the innovative efforts of the agents surprised in out-of-equilibrium conditions and the characteristics of the system affects not only the type of reaction whether adaptive or creative and the outcome of the innovative efforts, but also the structure of the system itself and its capability to provide access to knowledge externalities. Structural and technological change are intertwined in a dynamic process that is intrinsically historic and as such affected by the effects of contingent events that are determined by the stochastic evolution of events.

In this context longitudinal correlation in the sequence of events that take place along time can exhibit non-transitive properties so that while the correlation between event A at time t_1 and event B at time t_2 happens to be strong as well the correlation between event B at time t_2 and event C at time t_3, the correlation between event A and C can happen to be very weak (David, 2005 and 2007).

The appreciation of the path dependent character of these dynamic processes questions the use of Standard Markov chains. Standard Markov chains in fact are dynamic stochastic processes characterized by the presence of discrete values of the states and, more importantly, by the fact that the conditional probability of a state at time t depends exclusively on the state at time t-1. This implies that the process has no memory and only the last state influences the subsequent state. When the process is path dependent, instead, Multiple Probability Transition Matrices (MPTM) apply. MPTM consists in the computation of different probability transition matrices in relevant sub-periods, which are identified by significant contingent events that are expected to affect the transition probabilities between the innovative and non innovative status of the agents. The comparison of the parameters of the MTPM in different subperiods allows a better identification of the path dependent character of the innovation process. In particular, the observation of significantly different parameters for the MTPM in different subperiods might be an indication of the fact that the extent of the hysteresis is indeed affected by contingent events and, hence, the innovation process can be qualified as path-dependent (Antonelli Crespi Scellato, 2013).

Evolutionary approaches that apply the tools of complexity analysis can benefit greatly from a better and wider command of the history of economic analysis. A better appreciation of the Schumpeterian legacy and the careful analysis of its evolution, enables the inclusion of the tools provided by the Classical School, the Marshallian tradition and the historic foundations of economics dynamics into the toolkit of complexity approaches so as to provide stronger foundations to their applications to economic analysis.

4. CONCLUSIONS

Evolutionary economics is moving away from biological analogies towards the systematic use of the tools of complexity analysis. The attempts to build an evolutionary approach upon biological analogies have provided important results in analyzing the diffusion of innovations and their effects upon economic growth. Economics of innovation has benefitted greatly from the early advances of the evolutionary approaches based upon biological analogies. Their limit however is becoming more and more apparent.

The claim that evolutionary economics explains why and how innovation is endogenous and does not fall from heaven like manna has not been yet fulfilled. Biological evolutionary economics risks to be more exposed to the very basic criticism to neoclassical economics according to which innovation is exogenous. The understanding of innovation an endogenous and economic process can no longer rely upon the assumption that the variety within a system is perennially renewed by the random recombination of the basic traits of its agents.

Complexity provides a new framework to study innovation process as endogenous dynamics that are explained by the interactions among the agents that compose the system and among them and the changing characteristics of the system itself. The composition, organization, architecture of the system and the institutional context within which agents interact and participate into the collective endeavor of the generation and use of technological knowledge is the new basic clue upon which an endogenous understanding of innovation processes can be implemented.

Agents try and innovate. The new understanding of the unique features of the activities that enable to generate and use technological knowledge contributes to understanding the crucial role of the system into which agents are embedded in their effort to try and react to unexpected events by means of the introduction of innovations. The characteristics of the system can support or contrast their efforts. The introduction of innovations however changes the architecture of the system, its composition and organization. The effects can be positive as well negative with respect to its actual capability to support or contract the innovative efforts of agents. Hence it is clear that the characteristics of the system are endogenous and dynamic. This in turn makes clear that history matters in explaining the intertwining relations between the outcome of innovative efforts and the characteristics of the system, but not in a deterministic way. The dynamics is non-ergodic but path dependent as opposed to path dependent.

The prospects for important progress along these lines of enquiry are major. The retrieval of the tools provided by the history of economic analysis can help evolutionary complexity to move ahead. Biological evolutionary approaches have failed to include the theories of endogenous innovations elaborated in the history of economic analysis. The appreciation of the Schumpeterian legacy and specifically the correct understanding of the evolution of his analysis can provide a major contribution to this endeavor.

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