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by

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THE FIRM AS A DARWIN MACHINE:

HOW GENERALIZED DARWINISM CAN FURTHER THE DEVELOPMENT OF AN EVOLUTIONARY THEORY OF ECONOMIC GROWTH

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ABSTRACT

The debate on the ontological foundations of evolutionary economics has reached a stage where discussions of these foundations are increasingly leading to the conclusion that there is a need to move from considerations of the general principles of evolutionary theory to the development of concrete middle-range theories of specific economic phenomena. The purpose of this paper is to engage in such an exercise. I explore to what extent the general principles of generalized Darwinism can further the development of an evolutionary theory of economic growth. I will demonstrate the value of generalized Darwinism in two steps. First, by showing how its explanatory logic helps identify some limitations in the seminal theories of economic growth developed by Schumpeter, Penrose, and Nelson and Winter. Second, by showing how the Darwinian logic helps integrate the strengths of these three theories. The result of this exercise is a theory of the firm as a Darwin machine that better captures the interplay of agency and structure in the accumulation of productive knowledge, which is central to the phenomenon of economic growth that Schumpeter, Penrose, and Nelson and Winter set out to explain.

1. INTRODUCTION

The purpose of the project of Generalized Darwinism (GD) in evolutionary economics is twofold (Aldrich et al., 2008; Hodgson & Knudsen, 2006; Stoelhorst & Hensgens, 2006). The first objective of GD is to derive a general understanding of what an evolutionary explanation entails. The premise of GD is that such a general understanding can be derived from Darwin's theory of biological evolution by abstracting from all content that is specific to biology (Hodgson, 2002; Stoelhorst, 2008a). However, a general understanding of the explanatory logic of Darwinism can never be enough to build economic theories (Hodgson & Knudsen, 2006). Evolutionary theories always require an additional specification of their units of analysis and the details of the Darwinian mechanisms that explain the evolution of these particular units of analysis. Therefore, the second objective of GD is to develop better economic theories by applying the explanatory logic of Darwinism to specific economic phenomena.

Doubts about the usefulness of the project of GD come in two guises. The first doubt is if generalizing Darwinism is possible at all. This doubt stems from the belief that attempts to derive a general understanding of the explanatory logic of evolutionary theories that take their starting point in Darwinism are wrong-headed, because they carry the risk of constructing analogies to biological evolution that may be misleading when applied to economic phenomena (Cordes, 2006; Nelson, 1995, 2006; Witt, 2004; 2006). Note that the critics who have voiced this doubt do not call into question the usefulness of deriving a general account of evolution as such: both Nelson (1995) and Witt (2003) have put forward statements about the generic nature of evolution, albeit statements that differ markedly, with Nelson emphasizing selection and Witt emphasizing novelty. Rather, their doubt derives from an

understandable concern that evolutionary economists may get hung up on misleading biological analogies when building theories on Darwinian precepts. The retort from advocates of GD to this concern has been threefold: first, that so long as GD makes use of biological analogies, it has not reached its first objective, because its explicit aim is to rise above such analogies and to identify ontological communalities across all classes of evolutionary processes (Aldrich et al., 2008; Hodgson, 2002; Stoelhorst, 2008a; Stoelhorst & Hensgens, 2006); second, that a generalization of Darwinian principles that completely abstracts from specific biological content is not only possible (Aldrich et al., 2008; Stoelhorst, 2005) but has been achieved (Stoelhorst, 2008a); and third, that the resulting statement of generic evolutionary principles provides a more powerful logic for building *explanations* of economic phenomena than the competing statements offered by critics of GD, which are descriptive in nature and do not yet offer a alternative for the causal logic offered by GD (Stoelhorst, 2008a).

The second doubt about the project of GD does not call into question the possibility of generalizing Darwinism, but raises doubts about its usefulness. Here the criticism is that generalizing Darwinism may well lead to a generic understanding of what an evolutionary explanation entails, but that such a generic understanding is likely to be relatively useless for building theories of specific economic phenomena because it shifts all the explanatory burden to the auxiliary theories needed to fill in the details of the explanation (Buenstorf, 2006; Vromen, 2007; Levit, Hossfeld & Witt, 2010). It is this second doubt that motivates the current paper.

The purpose of this paper is twofold. Its first purpose is to contribute to the second objective of the project of GD, i.e. to apply GD to building theory about a specific economic

phenomenon. The phenomenon that will be examined in this paper is economic growth, which has arguably been the main focus of theory development in evolutionary economics from its inception. The second purpose of the paper is to dispel some of the doubts about the usefulness of GD in developing economic theory. I hope to demonstrate the usefulness of GD by showing that an application of its explanatory logic to economic growth theory can contribute to our understanding of economic growth above and beyond the seminal theories developed by Schumpeter (1934), Penrose (1959) and Nelson and Winter (1982).

The paper proceeds in four steps. First, I will argue that economic growth is at heart a learning process. The qualitative dimension of economic growth is the result of changes in productive knowledge. Second, I will argue that the learning process that leads to an changes in productive knowledge can be understood as an evolutionary process, and I will specify the generalized Darwinian principles on which an explanation of changes in productive knowledge can be build. Third, I will use the causal logic of generalized Darwinism to assess the theories of economic growth that feature in the seminal contributions to evolutionary economics of Schumpeter (1934), Penrose (1959), and Nelson and Winter (1982), respectively. The objective of this exercise is to show that the generalized logic of Darwinism serves a useful purpose in highlighting the relative strengths and weaknesses of the different theories of economic growth developed by these authors. Fourth, I will use the logic of GD to combine and extend elements of the theories of Schumpeter, Penrose, and Nelson and Winter into a theory of economic growth that sees firms as ‘Darwin Machines’ that accumulate productive knowledge over time.

2. ECONOMIC GROWTH AS A LEARNING PROCESS

The seminal theories of economic growth developed by Schumpeter (1934), Penrose (1959), and Nelson and Winter (1982) that will be reinterpreted below have interpreted economic growth as an evolutionary process. In doing so, their emphasis has been on economic development, or in other words, on qualitative change of the economic system from within. Interestingly, however, the authors of two of the three theories, Schumpeter (1934) and Penrose (1952), emphatically distanced themselves from the use of Darwinian logic in building evolutionary theories of economic phenomena, while Nelson and Winter (1982) saw their approach as Lamarckian. So why forge a link between economic growth and Darwinism?

The view of economic growth that is central to this paper is that economic growth is the result of a collective learning process. What evolutionary theories in economics have in common is that they emphasize qualitative changes in productive knowledge, the phenomenon that neoclassical theories relegated to the static abstraction of a production function. Neoclassical economics treats the firm as a black box that somehow transforms inputs (factors of production) into outputs (products and services). Where the productive knowledge that allows a firm to do so comes from is outside of the analysis, as is the process of the growth of this knowledge. Evolutionary theories of economic growth set out to address this process. It should be uncontroversial that knowledge is the result of learning. In other words, when developing accounts of the growth of productive knowledge, evolutionary economists ultimately are engaged in developing theories of a collective learning process.

Capturing the process of learning and the nature of the knowledge that results from it is a major challenge for theory construction. Simple unidirectional causal explanations at a single

level of analysis fall short of capturing the feedback loops and multi-level dynamics central to learning. Note that knowledge, the dependent variable of a theory of learning, is a *state* of the organization, and that this state results from the *process* of learning. In other words, the explanation of knowledge does not rest on an independent variable (or a set of those variables), but rather on a process in time. This calls for another causal logic than the typical explanation of the type 'X causes Y'. The reason for forging a link between Darwinism and theories of economic growth is that the explanatory logic of Darwin's theory of evolution can help us to deal with the theoretical complications inherent in conceptualising learning. As will become clear below, a generalized version of Darwinism is uniquely suited to capture the multi-level dynamics and feedback loops that are central to learning.

In fact, arguments from the branch of philosophy known as evolutionary epistemology lead to an even stronger claim: that learning is, by its very nature, a Darwinian process, that can *only* be understood in Darwinian terms. It is widely appreciated that Darwin's theory explains how the various adaptations of life forms to their environments come about. Building on a longer tradition in evolutionary epistemology (Campbell 1974; Popper 1972), Plotkin (1994) has convincingly argued that adaptations and knowledge are essentially the same thing. '[A]ll adaptations are instances of knowledge, and human knowledge [as commonly understood] is a special kind of adaptation' (p.117).

Plotkin's argument builds on two features of adaptation. The first is their goal-directed nature. Every adaptation is 'for' something. The second is their relational quality. Every adaptation is some form of organization of the system relative to some feature of environmental order. Adaptations simply cannot be seen in isolation from the environmental factors that have provided the selection pressures for them. The goal-directed property of adaptations can only

result if adaptations are ‘in-formed’ by features of the world; ‘they are highly directed kinds of organization, and not random, transient structures that may or may not work. Adaptations do work, and they work precisely because of this ‘in-forming’ relationship between organismic organization and some aspect of the order of the world’ (Plotkin, 1994, p. 118). In other words, adaptations can thus be understood as beneficial features of a system shaped by interaction with the environment. This makes them similar to knowledge, as we commonly understand the term. Knowledge is similarly a highly directed form of organization (for instance, in the case of individual knowledge, of the neural networks of our brain) that is informed by features of the external world.

The insight that adaptations are a form of knowledge, and knowledge as commonly understood is a form of adaptation, is central to the argument that learning is an evolutionary process. If learning is the process that leads to knowledge and evolution the process that leads to adaptations, then the corollary of equating knowledge with adaptations is that learning is an evolutionary process. It follows that the Darwinian logic should be able to help us explain the process of learning that leads to knowledge. In fact, on the view of evolutionary epistemology, barring on omniscient and omnipotent designer, the variation-selection-retention logic of Darwinism is the only logically consistent and complete explanation to account for adaptations that has been developed to date (Dennett, 1995). This view leads to a rather stronger claim than that Darwinism may be helpful. If we accept the basic tenet of evolutionary epistemology, the implication is that we simply have no other known recourse than Darwinism to ground theories of learning in a rigorous causal logic.

3. THE LOGIC OF A DARWINIAN EXPLANATION

Before we turn to the discussion of economic growth as a Darwinian process in which productive knowledge is the result of a learning process, we first need to establish what we mean when using the term 'generalized Darwinism'. Since the first part of the project of generalized Darwinism (to derive a general understanding of the causal logic of an evolutionary explanation) is still ongoing, this question does not necessarily have an unequivocal answer. Both in the philosophy of science more generally (cf. Plotkin, 1994; Godfrey-Smith, 2009) and within discussion about the ontology of evolutionary economics more specifically (cf. Hodgson & Knudsen, 2006; Stoelhorst 2008a), statements of generalized Darwinism that differ in their details have been, and continue to be offered. In this paper, I build on my own version of generalized Darwinism (Stoelhorst, 2005, 2008a), which has the following central features:

1. Generalized Darwinism applies to *open, complex systems*: open in the sense that they require resources from their environment to maintain their functional integrity, and complex in the sense that their interactions with the environment involve the interaction of lower level components.
2. Generalized Darwinism explains three specific *explananda*: variety from common origins, adaptive fit, and the accumulation of design (cf. Dennett, 1995).
3. These phenomena are explained on the basis of the Darwinian *explanantia*: the variation, selection, and retention triumvirate. These explanantia can be defined generically as follows (Stoelhorst, 2008a): variation mechanisms increase variety in the characteristics of a set of entities; selection mechanisms reduce variety in a set of entities as a function of the characteristics of these entities; retention mechanisms maintain the characteristics favored by selection in the set of entities.

4. The crux of a Darwinian explanation of the adaptive fit of open complex systems does not lie in these mechanisms as such, but in the *recursive causal logic* established by their interplay. For an open complex system to evolve adaptive fit, there needs to be a positive feedback loop from the success of the system's behavior, i.e. the way it interacts with its environment, to the likelihood of reproducing successful behaviors in future interactions with the environment. To be able to complete this feedback loop, we need to distinguish two levels of selection: the system's behavior, on the one hand, and the 'deep structure' of the system, or the system's 'codex' (Williams, 1992; Wilkins, 2001), that codes for that behavior, on the other hand. In terms of Sober (1984), the system's behavior is the 'unit of selection of' and the system's codex is the 'unit of selection for'. The *positive feedback loop* between the *behavior* and *codex* of the system makes the Darwinian logic algorithmic (Dennett, 1995): when there are mechanisms of variation, selection, and retention, and their interplay sustains a positive feedback loop from the system's behavior to its codex, then, given enough time, the system will necessarily become adapted to its environment.
5. The crux of a Darwinian explanation of the third explanandum, the accumulation of design, does not just lie in explanations of how open complex system evolve adaptive fit, but also requires explanations of the major transitions by which the evolutionary process lifts itself to higher levels of complexity (cf. Maynard Smith & Szathmary, 1997). This, in turn, requires a *multi-level selection logic* (Price, 1970, 1972; Maynard Smith & Szathmary, 1997; Sober & Wilson, 1998; Wilson & Wilson, 2007), in which the Darwinian mechanisms are seen to simultaneously operate at different levels of analysis. An example is how competition between individuals can nevertheless lead to cooperation in groups. The higher level of adaptive complexity of the group can evolve because the advantages that cooperation confers to individuals in between-

group competition can overcome the within-group competition between individuals inside the group.

Below, these five tenets of the Darwinian explanatory logic will be applied to explaining economic growth as a learning process. According to tenet number two, we need to specify our explanandum. As noted above, we set out to explain the qualitative growth of productive knowledge, which is a specific form of the accumulation of design. According to tenet five, we need to specify our units of analysis. In essence, a theory of the growth of productive knowledge needs to account for the process by which individual agency leads to the growth of collective knowledge. We will therefore apply a multi-level selection logic in which both individuals and firms are levels of selection. In doing so, the main focus of the analysis will be on the firm as an open complex system (tenet one) and our main task will be (1) to specify the nature of the codex of the firm as the carrier of productive knowledge (tenet 4), and (2) to specify the nature of the variation, selection, and retention mechanisms by which the codices of firms evolve (tenet 2).

4. AN ASSESSMENT OF SEMINAL THEORIES OF ECONOMIC GROWTH

Schumpeter: New combinations and the entrepreneurial function

Schumpeter (1934) is not concerned with economic growth as such, but with what he referred to as 'economic development'. The term 'development' is coined after dismissing the alternative label 'evolution' because 'the evolutionary idea is now discredited in our field' (1934, p.57).[1] Schumpeter makes clear that his interest is not in the historical phenomenon of economic change as such, which may well be the result of non-economic factors. Rather, his

[1] Nevertheless, in his later work, Schumpeter (1954) did use the label 'economic evolution' for 'all the phenomena that make an economic process non-stationary' (p.964), and described a narrower sense of economic evolution that seems to equate the phenomenon called economic development in his earlier work.

theory of economic development is a theory of economic change caused by purely economic factors, or in other words, a theory of change arising from within the economic system. Nor is his interest in economic dynamics in the sense of how an economy adjusts to external disturbances of economic data such as an increase of the population or changes of consumer tastes, phenomena that can be analyzed in terms of how an economy moves from one equilibrium point to another. Rather, the focus is on 'discontinuous changes in the traditional way of doing things' (p.62), 'the spontaneous and discontinuous change … which forever alters and displaces the equilibrium state previously existing' (p.64). Economic development, then, is 'that kind of change arising from within the system which so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps' (p.64, fn. 1).

It may be clear that the theory of economic development is a theory of *endogenous*, *qualitative* changes to the economic system – the sort of changes that are 'the fundamental impulse that sets and keeps the capitalist engine in motion' (Schumpeter 1943, p. 83) and that are the result, not of price competition, 'but the competition from the new commodity, the new technology, the new source of supply, the new type of organization … competition which commands a decisive cost or quality advantage … the powerful lever that in the long run expands output and brings down prices (ibid, p.84-85). In neoclassical terms, then, the concern is with changes in the production function, or the growth of productive knowledge.

How does Schumpeter explain the growth of productive knowledge? Two mechanisms are mentioned, enterprise and imitation, but only the former is developed in some detail. In fact, throughout the exposition in *The Theory of Economic Development*, the emphasis is on enterprise, or 'the carrying out of new combinations' (1934, p. 74). In this early work, Schumpeter emphasizes the role of individual entrepreneurs in carrying out new

combinations, while in his later work, where he acknowledges that in large firms entrepreneurship has become a more collective, and even routinized, endeavor he more generally refers to the entrepreneurial function. The carrying out of new combinations means 'simply the different employment of the economic system's existing supplies of productive means' (p.68).

In essence, the core of the theory is straightforward. There is heterogeneity in entrepreneurial abilities in the population. Individuals with entrepreneurial ability are able to do two things. First, they see possibilities for better use of existing factors of production that others do not see. Second, through their power of will they are able to redirect these factors of production to new uses. The combination of their vision and ability 'to get things done' leads to new combinations. In the short run, these new combinations result in entrepreneurial profits. In the longer run, these profits attract imitation, which will move the economy back towards equilibrium so that entrepreneurial profits remain a temporary phenomenon.

What is the causal logic of the theory? Answering this question leads to an immediate problem, because economic development and enterprise are defined in exactly the same terms: like enterprise (p.74), '[d]evelopment … is defined by the carrying out of new combinations' (p.66). It is therefore unclear what the dependent and, especially, independent variables in the theory are. Given the title of Schumpeter's work, it seems reasonable to define economic development as the explanandum and we might have expected entrepreneurship to be the explanans. But apparently, the two can be equated. This would seem to reduce the theory to a descriptive exercise of the phenomenon of economic development in terms of the carrying out of new combinations.

The assessment above may seem unfair, because, admittedly, there is rather more detail in Schumpeter's exposition of economic development than the bare bones version of his theory given above. There are also rich discussions of the role of credit, the nature of entrepreneurial profit, the role of interest on capital, and business cycles. But the fact of the matter remains that it is not at all obvious how his exposition *explains* economic development. In fact, if anything is explained, it is entrepreneurial profit, which is the temporary result from economic development. In this explanation, economic development is the independent variable, and the explanatory logic that is employed to explain how it leads to temporary profit is firmly embedded in the equilibrium logic of the 'circular flow' (cf. Hodgson, 1997).

Nevertheless, when we re-assess Schumpeter's exposition with the help of the causal logic of Darwinism, it is relatively easy to distill broad outlines of the Darwinian variation, selection, and retention mechanisms in Schumpter's exposition (cf. Kelm, 1997). The carrying out of routine operations is seen as the mechanism of retention. Enterprise is seen as the mechanism that introduces variation into the economy by carrying out new combinations. This variation is subject to selection by the market. If the new combinations are successful they are imitated and become part of routine operations. The economy has thus undergone qualitative change in the sense that the frontier of productive possibilities has shifted.

Given the fact that there are clear pointers to all three Darwinian mechanisms in Schumpeter's work, it seems fairly easy to begin to reconstruct his exposition in Darwinian terms. If we acknowledge that economic development can be understood as qualitative changes in productive knowledge, then Schumpeter's theory can be reinterpreted as stating that the interplay of routine operations, entrepreneurship, and selection by the market will lead to the accumulation of productive knowledge. However, what is less clear is where to look for the

different levels of selection that a Darwinian theory also requires. What are the systems that are competing, and what is the nature of their codices?

On this point, Schumpeter's early work is rather ambivalent. One possible interpretation is that we should consider the entrepreneur as the relevant level of analysis. If that would be the case, then we have individuals competing which each other, and we could presumably interpret economic growth as an individual learning process. On this view, productive knowledge would reside in the mind of the entrepreneur. However, at the same time, Schumpeter also seems to be reasoning in terms of firms competing with each other. It is not at all clear how these two units of analysis relate. In fact, Schumpeter's view of firms seems rather close to that of the view in neoclassical theory, where the firm is seen as a unitary actor that can be equated with the owner. In his early work, Schumpeter similarly seems to equate the firm with the owner/entrepreneur. But this is rather a gross simplification for a theory of the growth of productive knowledge as it seems to deny the collective nature of productive knowledge. Of course, in his later work, Schumpeter makes amends and acknowledges that the entrepreneurial function has become collectivized and, as he saw it, even routinized. But he never developed a theory of the role of organization in the growth of productive knowledge (Fagerberg, 2003). As a result, the precise nature of the recursive causal logic by which the success of new combinations is fed back into the actual organization of productive activities is not at all clear. What is missing in Schumpeter's exposition is a theory of the firm that is able to rescue productive knowledge from the abstract notion of the neoclassical production function.

Penrose: Resources, productive services and the administrative framework

Although Penrose repeats some of her earlier criticism of biological analogies (Penrose, 1952) in the introductory chapter of her book (Penrose, 1995 [1959]), she does use evolutionary terminology metaphorically. The term growth is used to denote 'an increase in size or an improvement in quality as a result of a process of development, akin to natural biological processes in which an interacting series of internal changes leads to increases in size accompanied by changes in the characteristics of the growing object' (p. 1). And 'growth is essentially an evolutionary process and based on the cumulative growth of knowledge, in the context of a purposive firm' (p. xiii). It is this qualitative change that she sets out to explain, and the size of the firm is seen as 'but a by-product of the process of growth' (p.2). Her theory explains the direction of expansion of the firm as driven by its 'inherited resources' (p.5) and the perception of productive opportunities by its managers. The rate of expansion of the firm is seen as being limited by the firm's capacity of experienced managerial resources.

As we may expect given her criticism of biological analogy, Penrose does not explicitly develop her theory of the growth of the firm in terms of variation, selection and retention. She is, however, quite explicit about the elements of the firm that are central to her analysis of how firms change: firms are seen as a collection of resources governed by an administrative framework. With this definition, and in marked contrast to Schumpeter, her view of the codex of the firm is immediately clear: the specific resources in the firm's possession and the way in which they are administered provide stability to the firm's activities. However, the resources are also a potential source of variety in the firm's activities over time. This is because each resource can provide a variety of productive services. Whenever there is excess capacity of resources and the firm perceives a productive opportunity, it will expand its activities. The resources of the firm thus both enable and constrain its growth.

Resources come in two forms: they include the employees of the organization as well as any other productive resources. Managerial resources are central to the argument: there needs to be an excess capacity of experienced managerial resources for firms to pursue new productive opportunities. The specific productive opportunities that are in fact pursued depend on the way managers perceive the competitive environment. 'The environment is treated, in the first instance, as an 'image' in the entrepreneur's mind of the possibilities and restrictions with which he is confronted' (p.5). This results in a rather voluntaristic argument. '[T]he environment is not something 'out there, fixed and immutable, but can itself be manipulated by the firm to serve its own purposes' (p.xiii). It is therefore not demand that limits the growth of firms, but the internal developmental process: 'a firm's rate of growth is limited by the growth of knowledge within it, but a firm's size by the extent to which administrative effectiveness can continue to reach its expanding boundaries' (p. xvii).

Restated in Darwinian terms, the firm's resources and its administrative framework serve as the source of stability in its activities, the different possible productive services of resources as a source of variety, and managerial perceptions of the environment as the source of selection. However, what the Penrosian theoretical structure is missing to qualify as a fully developed Darwinian account of learning is the feedback loop by which information on what works and what doesn't work is fed back into the firm. This is already clear in the introductory chapter, where she addresses the 'alleged tautological problem which some have feared is inherent in a theory of the growth of firms concerned only with firms that can successfully grow' (p.7). What follows is a rather unconvincing argument in which she states that here concern is merely to answer the question: 'assuming that some firms can grow, what principles will then govern their growth, and how fast and how long can they grow?' (p.7).

The rest of the book, of course, develops an admirable answer to this question. But the argument would have certainly gained in strength if it had also incorporated an explicit analysis of the effects of competition between firms on their relative success. In the Penrosian view, the experienced manager almost takes the form of an omniscient designer. It is his 'image' of the productive opportunities in the environment that matters 'for it is, after all, such an 'image' which in fact determines a man's behaviour; whether experience confirms expectations is another story.' (p.5). The qualifier on which this statement ends seems to be an afterthought. However, a Darwinian account means also telling that other story.

Nelson and Winter: Genes, routines, and organizational memory

Nelson and Winter (1982) set out to develop a theory of economic change that is first and foremost concerned with explaining phenomena at the level of industries. Yet, one of their important achievements was that they grounded their theory in a rich discussion of the inner workings of the firm, and another that they framed this discussion in explicitly Darwinian terms.[2] Given their explicit use of Darwinian terminology, let us first consider what Nelson and Winter say about the mechanisms of variation, selection and retention that shape organizational change. The central concept in Nelson and Winter's work is that of an organizational routine. Routine is their 'general term for all regular and predictable behavioral patterns of firms' (p. 14), and it is this regular, predictable and recurrent behavior that is the centerpiece of an evolutionary logic in which 'routines play the role that genes play in biological evolution' (p.14). In other words, routines provide the necessary stability in behavior over time that is required for the Darwinian algorithm to work. More specifically, it is by exercising routines that an organization retains its productive knowledge. In addition, of course, there need to be consistent selection pressures and a source of variation. The first is

[2] This is despite calling their theory Lamarckian. For a convincing discussion of why Nelson and Winter's work can be appropriately viewed as Darwinian see Hodgson (2002).

provided by the scarcity of resources for which firms compete in the market, and the second by higher level 'search' routines by which firms look for ways to modify their lower level 'operating' routines.

How does this view of the firm map unto the Darwinian logic discussed above? Unfortunately, this is not at all clear. As has been pointed out elsewhere, there are some ambiguities in Nelson and Winter's treatment of routines (Hodgson 2002; Becker 2004). If routines were the analogue to genes, we would expect them to be what codes for functional behavior and not to be defined in terms of the behavior itself, as Nelson and Winter do. The notion of 'routines as genes' would mean that we are talking about the firm's codex, yet the definition of routines as recurrent patterns of behavior immediately shifts our focus to what is actually selected by the market. In other words, *the notion of organizational routines conflates the codex and behavior of the firm.* What we are left with is a view of the firm as a set of recurrent action patterns that are subject to selection by the market. What the source of variation in these patterns is, or how they are retained through time, is not clear.

Whereas it is easy to distil the three Darwinian mechanisms from Nelson and Winter's work, it is not immediately clear how we can derive insights about the codex of the firm from their work. To better understand the nature of the codex we need to specify both the sources of variety and the sources of stability in the behavior of firms. Merely using the notion of routine as shorthand for the claim that there is such stability over time will not do. Rather, we have to unearth the actual mechanisms that give rise to recurrent action patterns (Becker, 2004). Nor does invoking higher-level routines as a source of change in lower level routines help much in understanding the source of variety in the behavior of firms. This is a way of hiding individual behavior and initiative in the folds of an infinite regress of ever-higher levels of routines (cf.

Winter, 2003). This way of treating the sources of variety is ironic for a theory that professes to be 'unabashedly Lamarckian' (p.11), because it does away with the need to incorporate intentional behavior in an explanation of how firms learn. In fact, as the nature of their formal models shows, the resulting explanatory logic works equally well with variety that is generated blindly. By modeling the codex of the firm in terms of a hierarchy of routines and by thus putting all the explanatory power of the theory in the collective phenomenon of routines, the role of individual behavior in shaping the actual behavior of firms is lost (Stoelhorst, 2008b).

The fact that Nelson and Winter conflate codex and behavior and view the codex of the firm in terms of a hierarchy of routines is best understood in light of their goal to construct quantitative models of industry-level phenomena. There is a notable difference between these modeling efforts and the so-called 'appreciative theorizing' in the first chapters of their book. In fact, the problematic notion of routines hides a subtle discussion of the internal workings of the firm that gives more detailed pointers to the mechanisms that may account for the simultaneous stability and change in the behavior of firms. In their discussion of 'routine as organizational memory' Nelson and Winter discuss individual members of the organization as the locus of much of the information that is required for the performance of organizational routines, but emphasize that organizational memory is not reducible to the memories of individuals. This would 'overlook, or undervalue, the linking of those individual memories by shared experiences in the past, experiences that have established the extremely detailed and specific communication system that underlies routine performance' (p. 105).

This seems to establish two points. First, individual behavior does matter in understanding the routines of firms. Second, individual behavior can become part of a recurrent pattern of

coordinated behavior by responding to an 'extremely detailed and specific communication system'. It would seem that it is this communication system that we need to unravel to really understand the nature of the codex that provides the stability in coordinated behavior. This idea is reinforced by Nelson and Winter's remark that to establish a new routine where non exist before, 'organization members have to learn the system of coordinating messages. They may have to add new skills to their individual repertories, and they need to achieve a first reconciliation of their expectations regarding the distribution of costs and benefits in the new situation' (p.112).

The comment about a reconciliation of expectations relates to their discussion of 'routine as truce'. Again we see an explicit consideration of how individual behavior becomes part of a coordinated action pattern. Whereas the 'routine as organizational memory' considers the cognitive aspect of how individuals behave (do they know what to do, and how to do it), the 'routine as truce' considers the motivational aspect (do they actually choose to do what is required of them in the routine operation of the organization as a whole). Nelson and Winter emphasize that 'routine operation should not be confused with performance according to the nominal standards of the organization' (p.108). 'The usual mechanisms of internal control are, of course, a part of the context that helps define the *de facto* contracts that individual members make with the organization' (p.108-9). But '[w]hat signals the existence of an accommodation is not the conformity of behavior to standards of performance laid down by supervisors or codified in job descriptions, but that members are rarely surprised at each other's behavior …' (p.108). 'In routine operation, the combined effect of the rule-enforcement mechanism and other motivators is such as to leave the members content to play their roles in the organizational routine – but content only in the sense that they are willing to continue to

perform up to their usual standard …In short, routine operation involves a comprehensive truce in intra-organizational conflict' (p.110).

We may conclude that Nelson and Winter's idea of routines as the building blocks of organizational capabilities is problematic, because both routines and capabilities are defined in terms of behavior, and not in terms of the knowledge that underlies and enables that behavior. The idea of a hierarchy of routines, while useful as a modeling tool, does not help unravel where and how organizational knowledge is stored in ways that allow the firm to repeat functional behaviors over time. By itself, the notion of routines as the genes of organizations does not tell us anything about how individual behaviors can become part of coordinated behavior patterns. However, the discussions of 'routine as organizational memory' and 'routine as truce' begin to convey a picture of individuals adapting to a complex intraorganizational environment consisting of a 'system of coordinating messages' (p.112), an 'organizational dialect' (p.104), and 'a peculiar symbolic culture' (p.111). Moreover, routines can also take on the quality of norm or target, and be 'imposed on a continually changing set of resources' (p.113). On this view, what seems to be needed is a more detailed explanation of how individual learning relates to the growth of collective knowledge.

5. TOWARD A DARWINIAN THEORY OF ECONOMIC GROWTH

Our assessment of the three evolutionary theories of economic growth above leads to the conclusion that all three are ambiguous about the nature of the causal logic they employ. While each theory offers important insights into the process of economic growth, none of them achieves a full specification of all the theoretical building blocks that the Darwinian logic calls for. However, together, they can be seen to supply most of these building blocks

and an integration of their insights can bring us closer to a causal account of economic growth as a process of collective learning that increases the stock of productive knowledge.

In Schumpeter's account, the level of analysis is the economy as a whole, the emphasis is on entrepreneurship as a variation mechanism and competition as a selection mechanism, but retention mechanisms are not developed. Economic growth is understood in terms of qualitative changes to the economy that shift the frontier of productive knowledge. Economic growth is the result of entrepreneurial behaviors that move the economy away from the old equilibrium and competitive behaviors that move it back towards a new equilibrium. Competitive behaviors take the specific form of imitation. The dissemination of the new productive knowledge that is inherent in the new combinations that the entrepreneurial function brings to market is treated as a frictionless process. Where productive knowledge actually resides is not made clear. In Schumpeter's early work, the view seems to be of the economy as a system of competing individuals, while in his later work, he seems to emphasize competition between firms. How these two levels of analysis relate to each other is not developed. What the Schumpeterian account lacks to complete a convincing causal logic is a theory of productive knowledge in terms of the internal operations of a firm.

In Penrose's account, the level of analysis is the firm and the emphasis is on mechanisms of variation and retention, but competition as a mechanism of selection is, at most, in the background. Penrose's account can be understood as complementing Schumpeter's, in the sense that she provides a fuller specification of the internal operations of the firm. Firms are seen as collections of resources that are 'bound together' in an administrative framework. Resources come in two forms: they include both the individual members of the organization and the (im)material assets that are at the firm's disposal. These resources, together with the

administrative framework that governs how they interact, both enable and constrain the behaviors of the firm. What is not clear from the Penrosian account is how firms are able to adapt to their environments and develop functional behaviors. What her theory lacks to establish a convincing causal logic is an explicit feedback loop from the success, or lack thereof, of firms' interactions with the market to the configurations of their resources and administrative frameworks.

This feedback loop is central to Nelson and Winter's account of economic growth, which emphasizes selection by the market. Given their explicit use of a Darwinian analogy, their account specifies mechanisms of variation, selection, and retention, but in doing so, the role of individual behavior, although considered important, is pushed into the background. In their formal models, the relative profitability of the activities of the firm determines the expansion or contraction of these activities. However, by simply postulating the existence of operational routines as a mechanism of retention, and the existence of higher-level search routines to modify the operational routines as a mechanism of variation, these models sidestep the question how this expansion or contraction is actually achieved. The notion of routines nicely captures the idea that productive knowledge is expressed in more or less stable collective behavior patterns. But it does not, as such, explain the causes of this stability. To qualify as a complete specification of a causal account of the growth of productive knowledge, Nelson and Winter's account needs an explanation of how interactions among individual organization members can result in the stable collective behavior patterns that underwrite a firm's success in the market. In other words, what is needed is a specification of the nature of the codex of a firm.

Our assessment of the theories of economic growth developed by Schumpeter, Penrose, and Nelson and Winter points to two conceptual gaps that need to be filled to be able to ground their theories in Darwinian logic: (1) the need to develop an explicit understanding of where productive knowledge resides, or in other words, of the nature of the codex of a firm, and (2) the need to embed arguments about the growth of this knowledge in a multi-level logic that is able to integrate accounts of the role of individual agency in economic growth, on one hand, and accounts of the role of collective behaviors of firms, on the other.

In essence, economic growth is a collective learning process, by which the stock of productive knowledge in the economy as a whole increases. To explain this learning process in Darwinian terms, we need to, first, specify our units of analysis. These are twofold. In keeping with Schumpeter's and Penrose's emphasis on individual behaviors, on the one hand, and Penrose's and Nelson and Winter's emphasis on the collective behaviors inside firms, on the other hand, the units of analysis in the Darwinian theory of economic growth proposed here are individuals and firms. Thus, economic growth is explicitly seen as a phenomenon that results from multi-level selection processes that unfolds as the joint result of competition between individuals and competition between groups.

Our second task is to specify the nature of productive knowledge. In a Darwinian theory of economic growth, the codex is the carrier of productive knowledge. Therefore, given our multi-level selection characterization of the process of economic growth, the task of specifying where productive knowledge resides amounts to specifying codices at the individual and the firm level. At the individual level, this is straightforward: here the codex can be understood as the neural connections in the brain. It is these connections that

underwrite individual behavior, and it is these connections that evolve as an individual learns about behaviors that work in relation to the local environment.

To specify the nature of the codex at the level of the firm is a more demanding task. In essence, the question that we face is to account for the stability of the collective behavior patterns that Nelson and Winter refer to as routines. In fact, Penrose's account of the firm as a collection of resources bound together in an administrative framework can be understood as a step towards such an account. Let us start with resources. On Penrose's view, resources encompass both human and non-human resources. Both can be understood as carriers of productive knowledge. In the case of individuals, they carry productive knowledge in their brains, as specified above. In the case of physical resources, they carry productive knowledge that results from the designs that underlie their functionality.

The second element of Penrose's view of the firm is the administrative framework. Unfortunately, this is a concept that she did not develop in much detail. However, it is clear that the administrative framework governs the specific uses that are made of the productive services that a firm has at its disposal. In that sense, the administrative framework is essential in accounting for the stability of the collective patterns of behavior on the basis of which firms compete. Ownership of particular resources as such cannot explain these patterns; it is how they interact that determines if firms can successfully interact with their environments. In other words, the question that we face in unraveling the nature of the administrative framework as part of the codex of a firm is how it underwrites stable collective patterns of behavior.

This question can be answered by considering firms' administrative frameworks in terms of roles and rules. The administrative framework can be understood as assigning roles to human resources and establishing rules about the way a firm's human and non-human resources should interact. On this view, the specification of the codex at the level of the firm encompasses its *resources*, *roles*, and *rules*. This is where the collective phenomenon of productive knowledge resides. It is its specific configuration of resources, roles, and rules that underwrites a firm's way of interacting with its environment. Firms interact with their environments through market transactions, and these interactions may be seen as the 'unit of selection of'. But underlying a firm's success, or lack thereof, in market transactions is its configuration of resources, roles, and rules. This configuration is the 'unit of selection for'.

It may be clear that in the theory of economic growth proposed here, firms are seen as the carriers of productive knowledge. Economic growth is the result of the accumulation of productive knowledge that takes the form of changes in firm's configurations of resources, roles, and rules. In Schumpeterian terms, economic development takes the form of 'new combinations' of resources, roles, and rules that allow firms to create new value. However, despite the focus on the collective nature of firms in the specification of the locus of productive knowledge, in the theory that is proposed here individuals are seen as the only source of novelty in the economic system. An accurate specification of the mechanisms of variation, selection, and retention that drive economic growth therefore needs to proceed in terms of individual agency.

When detailing the mechanisms of variation, selection, and retention in a Darwinian theory of economic growth, it is essential to take into account the multi-level nature of the selection processes involved in the growth or productive knowledge. At the level of *between-group*

competition, i.e. at the level of competition among firms, the sources of *variation* are the new market offerings introduced by new or established firms. These new products (or services) increase variety in the set of entities from which buyers can select. The sources of *selection* are twofold: they are the decisions of buyers to favor certain products over others, and the decisions of competitors to imitate the products of competitors. Both mechanisms reduce the variety in the set of entities from which buyers can select. In the case of the decisions of buyers, variety will be reduced because a lack of success will lead to the elimination of unsuccessful market offerings, either through discontinuation of individual products, or through the outright failure of the firm offering the products (on a similar logic as survival selection in biology). In the case of imitation of successful products by competitors, variety will be reduced because of the homogenization of market offerings (on a similar logic as sexual selection in biology). Finally, the sources of *retention* are the resource, roles, and rules that allow firms to reliably produce successful products. Success in the market will reinforce the existing configuration if resources, roles, and rules that underlie the market offerings of the firm.

The second level of selection that we need to detail in our multi-level selection framework is that of *within-group competition*, i.e. the level of competition among individuals. Here the sources of *variation* are changes in individual behaviors. These can result either from the introduction of new individuals within the group, or through the experimentation with different behaviors of existing members of the group. At this level of analysis, the *selection* environment consists of the prevailing configuration of resources, roles, and rules. In varying their behavior within the group, individuals will learn which behaviors work in the local context of existing resources, roles, and rules. The sources of *retention* are the neural connections in the brain of the individual. Behaviors that are successful will reinforce the

neural connections that trigger these behaviors, so that repetition of these behaviors will become more likely.

From this admittedly sketchy outline of a Darwinian theory of economic growth, it may be clear that the configurations of resources, roles, and rules that underwrite the collective behaviors of firms are seen as the repositories of productive knowledge. Note that these configurations include human resources with their idiosyncratic individual knowledge bases. It may also be clear that individual agency is seen as the only source of change in the theory.[3] Individuals vary their behaviors and learn about behaviors that work. They drive change through their behaviors as consumers and as members of firms. As consumers, their behaviors are the ultimate source of selection pressure on firms. As members of firms, their behaviors are the ultimate source of variation in the way productive activities are carried out. Finally, it may also be clear that competition is seen as the engine of change. Ultimately, this competition needs to be understood in terms of the competition between individuals. However, this competition goes hand in hand with the emergence of cooperation between groups of individuals to further their joint interests. The collective behaviors of groups of individuals are underwritten by specific configurations of resources, roles, and rules. These configurations, the repositories of productive knowledge, evolve as the joint result of within-group and between-group competition. In essence, then, economic growth is the result of qualitative changes in the configurations of resources, roles, and rules that underlie the productive activities of firms.

[3] This is not to say that external shocks to the economic system are negated, only that these are exogenous to the theory. The focus of the theory is on endogenous growth.

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