

Papers in Evolutionary Economic Geography

13.28

Towards a Developmental Turn in Evolutionary Economic Geography?

Ron Martin and Peter Sunley



Utrecht University

Urban & Regional research centre Utrecht

Towards a Developmental Turn in Evolutionary Economic Geography?

Ron Martin* and Peter Sunley**

*Department of Geography University of Cambridge, Cambridge CB3 0PP, UK

Email: rlm1@cam.ac.uk

** Geography and Environment, University of Southampton, Southampton
SO17 1BJ, UK

Email: P.J.Sunley@soton.ac.uk

March 2013

Revised Draft November 2013

Paper submitted to *Regional Studies*
Special Issue on Evolutionary Economic Geography
Editor: Dieter Kogler

Abstract

Over the past couple of decades or so, there have been increasing moves within evolutionary theory to move beyond the neo-Darwinian principles of variety, selection and retention, and to incorporate development. This has led to a richer palette of concepts, mechanisms and models of evolution and change, such as plasticity, robustness, evolvability, emergence, niche construction, and self-organisation. This opens up a different framework for understanding evolution. In this paper we set out the main characteristics of the recent and ongoing 'developmental turn' in evolutionary theory, and suggest how these might inform a corresponding 'developmental turn' in evolutionary economic geography.

Key Words

Evolutionary economic geography Generalised Darwinism Evolutionary
developmental biology Developmental systems theory Plasticity
Robustness Evolvability Emergence Self organisation

Perhaps it is not too much to say that what we need is an evolutionary theory worthy of the best social theory, not a social theory trimmed to fit a rapidly receding, overly simplistic evolutionary theory (Depew and Weber, 1995).

I remonstrate that only one side of the Darwinian narrative is currently being told - the eliminative aspects that derive from competition. It is the neglected half of evolution - i.e. the growth side - that more resembles developmental theory and deserves greater emphasis. (Ulanowicz, 2011).

1. Introduction: Rethinking Evolutionary Economic Geography

Explaining how ‘space makes possible the particular, which then unfolds in time’, to use the pithy phrase with which August Lösch begins the Epilogue to his masterpiece on *The Economics of Location*, has long been a recurring focus of enquiry in economic geography. Most often this focus has been subsumed under the general rubric of ‘regional development’, and over the years various theories have been advanced purporting to capture the characteristic patterns and processes involved. The recent rise of ‘evolutionary economic geography’ (EEG) can in one sense be seen as the latest attempt in this on-going endeavour (see Boschma and Frenken, 2006; Boschma and Martin 2007, 2010). Advocates of the new evolutionary economic geography - ourselves included - have championed the exploration of this perspective on the grounds that it pushes the analysis of regional economic *change and evolution* to centre stage, and have argued that much of the distinctiveness of the approach derives not just from giving primary emphasis to the ‘historical unfolding’ of the economic landscape, but also from the deliberate exploration and use of explicitly *evolutionary* concepts, analogies and metaphors inspired by evolutionary ideas and thinking developed in biology, physics, ecology and other such fields of enquiry. Of course, care must be exercised in using ideas from other disciplinary fields as metaphors and analogies for how we think about change in the economic landscape. For one thing, there may well be ontological limits to such abductions: as Alfred Marshall once quipped, “analogies may help one into the saddle, but are encumbrances on a long journey” (Marshall, 1898, p. 39). For another thing, and equally importantly, different evolutionary concepts embody or imply different models of change, with the consequence that their application in economic geography likewise implies different models of how regional economies change over time: such models of change, sometimes recognized explicitly, sometimes merely left implicit, include gradualism, path dependence, punctuated equilibrium, branching, emergence, and life cycles. Thus far, evolutionary economic geographers - again, ourselves included - have given relatively little attention to how far and in what ways these different underlying

models of change, and the theoretical perspectives from which they are drawn, relate to each other. Different models of evolutionary sequence may be applicable to some types of economic process and spatial scales and not others. This raises the question of whether and to what extent some sort of synthesis is possible, and thus whether, as a consequence, evolutionary economic geography can be given a more comprehensive and more integrated conceptual basis.

There is another compelling reason for posing this question. If there is one single conceptual approach that above others has tended to inform and motivate evolutionary economic geography, it is some invocation of the key Darwinian notions of variation, selection and retention, or VSR (see Essletzbichler and Rigby, 2007).¹ These same notions have played a formative role in the development of evolutionary economics, so it is not surprising that economic geographers should have been drawn to them in developing their own 'evolutionary turn'. Indeed, in this respect, both disciplines have been heavily influenced by a wider movement that has sought to construct a new over-arching research strategy of 'Generalised Darwinism' based on the assumption of a close homology between evolution in nature and the evolution of the socio-economy. Advocates of Generalised Darwinism invoke VSR as the central defining principles governing social and economic evolution. Evolutionary economic geographers have tended to adopt the same strategy: in their work, too, the notions of variety (and more recently 'related variety'), selection, and retention have been used to construct an evolutionary perspective on the spatial economy, including studies of how industries emerge and develop across space, how regional economies function as 'selection' environments, how far and in what ways various 'retention' mechanisms lead to the 'lock-in' of particular regional patterns of economic activity, and how spatial networks of economic relations and forms of spatial economic agglomeration (from clusters to cities) evolve through time, to name but some of the topics of interest.

However, within economics and other disciplines, the project of Generalised Darwinism has recently come under increasing critical examination. Even some of those evolutionary economists who previously drew extensively on the basic Darwinian framework in their work now seem to argue that invoking the concepts of VSR may not only be ontologically problematic, but also that these three principles of themselves do not suffice to explain economic evolution. There is growing doubt about how far Darwinism can be 'generalised' to the economic realm, and certainly whether its abstract principles provide an adequate basis for

¹ The terms 'inheritance', replication' and 'retention' are often used interchangeably in the evolutionary literature, and likewise also in evolutionary economics. But according to Campbell (1965), in socio-economic contexts 'retention' is preferable to 'inheritance' or 'replication' since the latter two are too loaded with biological connotations.

an evolutionary approach to economics. At the very least, the view seems to be emerging that additional principles and concepts for explaining the processes of economic change and evolution also need to be considered.

To compound matters, recent debates in evolutionary biology itself involve a major reassessment of the Darwinian-infused model. The Modern Synthesis, essentially a synthesis of neo-Darwinism and Mendelism, has defined evolutionary theory since the 1940s (see Futuyma, 1988). Over recent decades, however, there have been increasing moves to overcome what an expanding number of evolutionary theorists see as key limitations of the Modern Synthesis, including the tenets of VSR. These limitations are seen by a growing number of theorists as deriving in large part from the relative isolation of developmental biology from evolutionary biology. How to reconcile and integrate these two sciences has been discussed intermittently for some time, but recently two new synthesising endeavours have emerged that represent major steps in this direction, namely: Evolutionary Developmental Biology (EDB), or 'evo-devo' to use its commonly employed sobriquet, and Developmental Systems Theory (DST). Both, in their different ways, seek to expound how developmental processes effect evolutionary change and how development itself has evolved. Both seek to move beyond the 'gene-centred' approach of the Darwinian Modern Synthesis to recognize the multi-level and non-genetic aspects of evolution. And, importantly, both allow environmental and contextual resources and influences to have a formative role in how development and evolution co-interact. Of the two approaches, EDB retains the closest links with the Modern Synthesis, whereas DST is more radical in its approach. Furthermore, although EDB and DST derive from different basic conceptualizations of how evolution and development are (or should be) related, some of their tenets are not that dissimilar, and there is increasing interest in creating bridges between the two perspectives. Both seem to offer the prospect of a more pluralistic and systemic or holistic theory of evolution, one that incorporates additional levels of explanation than that provided by the Darwinian Modern Synthesis. Interestingly, some evolutionary anthropologists and cultural theorists have begun to examine EDB to ascertain what its implications might be for their disciplines (see, for example, Mesoudi et al, 2006; Wimsatt, 2006; Smith and Ruppel, 2011), and behavioural psychologists are applying DST in their field (for example, Lerner, 2006; Masten and Obradovic, 2006). Economists appear about to embark on similar exploratory expeditions (for example, see Pelikan, 2011, and Cochrane and Maclaurin, 2012, on the relevance of EDB for evolutionary economics). It is worth exploring, therefore, what the implications might be for evolutionary economic geography.

The more so because current evolutionary economic geography has already come in for some criticism. It has been charged as being too narrowly focused and for claiming to be an approach quite different from others in economic geography.

Its critics argue that what we should be seeking to develop is not ‘*evolutionary economic geography*’, but the treatment of ‘*evolution in economic geography*’ and the integration of evolutionary economic geography with existing theoretical frameworks, such as geopolitical economy or institutional economic geography, which, it is claimed, not only incorporate various historical arguments of their own but, unlike evolutionary economic geography, also take power and agency into explicit account (MacKinnon et al, 2009; Barnes and Sheppard, 2010; Coe, 2011; Oosterlynck, 2011).² Evolutionary economic geographers - ourselves included - would not only argue that such criticisms are somewhat premature (after all, the field of evolutionary economic geography is still in its infancy), but that power relations, embedded agents and institutions can all in principle be incorporated into an evolutionary perspective. The fact that progress has yet to be made on this front should not be taken to mean that evolutionary economic geographers view these features as unimportant or incompatible with their approach (see Boschma and Frenken, 2009; Martin, 2011). At the same time, however, evolutionary economic geographers – again, ourselves most certainly included – would also refute any suggestion that they are seeking to construct some all-embracing alternative ‘metatheory’. Rather, the ambition is more modest. Capitalism is a dynamic system of ongoing change and transformation, of incessant and uneven ‘creative destruction’, to use Schumpeter’s famous phrase: or, as Knight (1923, p. 184) once put it, “there is evolution in the nature of capitalism”. The aim of evolutionary economic geography, as we see it, is to explore what evolutionary principles can be identified that help to explain change and transformation in the economic landscape. To this end, and this to our mind is the key point, whether the aim is to develop the treatment of ‘*evolution in economic geography*’ or to prosecute ‘*evolutionary economic geography*’ as a distinctive paradigm, it is surely important that the ideas we utilize and adapt reflect the latest thinking in evolutionary theory. Writing over a decade ago, Metcalfe argued that “as economists applying evolutionary ideas to economic phenomena, we can learn from the debates on evolution in biology... without in any sense needing to absorb the associated biological context” (1998, pp.21-22). That is precisely our sentiment here.

But we need to make our purpose clear. We are not arguing that ‘Generalised Darwinism’ (largely via its use in evolutionary economics) has been the *only* source of inspiration in evolutionary economic geography (EEG):

² A not dissimilar argument has been made by certain mainstream economists against the need for a separate discipline of evolutionary economics. They are of the view that conventional economic theory can in fact explain evolutionary phenomena and processes (see Krugman, 1996).

obviously that is not the case. Some authors have expressed interest in ideas borrowed from the theory of complex adaptive systems: indeed we have explored such ideas ourselves (see Martin and Sunley, 2007, 2011, 2012). And of course the notion of path dependence is frequently invoked in evolutionary economic geographical accounts: again, we have contributed to the development of this notion for studying change and continuity in the economic landscape (Martin and Sunley, 2006; Martin, 2010, 2013). However, it is the case that, explicitly or implicitly, ideas from Generalised Darwinism have played, and continue to play, a significant role in EEG, and it is this body of evolutionary notions and metaphors that has recently attracted reappraisal from within evolutionary biology and evolutionary economics. This reappraisal, moreover, involves the incorporation of ideas from complex adaptive systems. These developments provide the motivation for this paper. In our view, there are two main tasks: to update the range of evolutionary concepts and constructs that might be deployed, to take account of new developments within evolutionary theory itself; and to develop an expanded theoretical architecture that allows engagement with relevant ideas and arguments to be found in other approaches to economic geography, particularly those that focus on uneven regional development. Each task is itself a major exercise: to successfully accomplish both is far beyond a single paper. What follows, therefore, is merely an initial attempt to chart one possible route by which to travel towards that destination, namely the idea of constructing what might be called an ‘evolutionary developmental economic geography’.³ Our focus is on establishing an expanded evolutionary-geographical conceptual apparatus, since that is the vital first step; the discussion of how to put that apparatus into empirical action, the second step, is beyond the scope (and length) of this paper, though we do offer with brief thoughts on this issue. We begin with an examination of the limits of Generalised Darwinism as a basis for evolutionary economic geography.

2. Evolutionary Economic Geography: Moving Beyond Generalised Darwinism

As noted above, neo-Darwinian evolutionary ideas have been important to the emergence of evolutionary economic geography in two main ways. Firstly, the subfield has drawn much inspiration from the way that evolutionary economists have used Darwinian-infused notions in a metaphorical and analogical manner

³ The paper is the latest in an ongoing series in which our aim has been to explore and evaluate the scope and limits of various conceptual approaches to evolutionary economic geography, not in any belief that there is a single superior all-embracing framework to be discovered, but to identify novel evolutionary metaphors, notions and principles that seem to us to be potentially useful in expanding the conceptual reach and empirical concerns of the subject.

(such as Nelson and Winter, 1982; Metcalfe, 1998; Witt, 2003). In particular, most of the foundational contributions to evolutionary economic geography have drawn upon Nelson and Winter's (1982) argument that in the economic sphere it is business routines which demonstrate the key neo-Darwinian processes of variation, selection and replication or retention (Boschma 2004; Boschma and Frenken, 2006). Just as genes are the main replicators of biological information, so business routines are frequently viewed by evolutionary economists and evolutionary economic geographers as playing an analogous role in the economy:

The appropriate unit of selection is, I suggest, an organizational cum technological complex: a set of instructions for translating input into output for a purpose. This complex is constituted by the set of routines to guide behaviour, routines which collectively constitute the knowledge base of the particular activity. We shall call this complex a business unit... (Metcalfe, 1998, p. 27).

Heterogeneity and variety in routines are argued to fuel a selection process driven by competitive markets (what Metcalfe calls a process of 'competitive selection').

Secondly, the influence of neo-Darwinian thought has been strengthened in recent years by the consolidation of what has been called 'Generalised Darwinism' (see Hodgson, 2002; Hodgson and Knudsen, 2006, 2010; Aldrich et al, 2008). This approach argues that all evolutionary processes, including those in the economic domain, are characterized by the operation of the three key principles of VSR. Although it is recognized that the specific nature and operation of these principles are quite distinct in different fields, and that economic instances differ from their biological counterparts, nevertheless according to Hodgson and Knudsen (2006, 2010) we cannot have satisfactory explanations of how economic systems evolve that do not refer to these three principles (also see Metcalfe, 1998). This assumption has been carried over into evolutionary economic geography, where the challenge is seen as one of identifying the specific instances of VSR responsible for spatial economic change (see Essletzbichler and Rigby, 2007).

In recent years, however, the appeal to neo-Darwinian ideas has been subject to growing reassessment within evolutionary economics. This critique is partly rooted in a concern about the difficulties in translating these ideas into social theories. Witt (2004), for example, highlights how the metaphors of VSR are in some ways ill-suited to understanding processes of human creativity and learning. In his view "The selection metaphor may therefore divert attention from what seems to be crucially important for economic evolution – the role played by cognition, learning and growing knowledge" (2004, p. 128). Others point out that such metaphors yield an approach that is overly micro-focused and which fail to consider the more holistic features of an economic system (Foster, 2010). Such questioning has been intensified by the recent critical reaction to Generalised Darwinism (see Nelson, 1995, 2007; Buenstorf, 2006; Vromen, 2007, 2008; Levit,

Hossfeld and Witt, 2011). Interestingly, while maintaining that neo-Darwinian evolutionary theory illuminates some aspects of economic change, even Richard Nelson now warns that socio-cultural evolution should not be shoe-horned into a standard Darwinian framework, and that fundamental differences exist between the biological and socio-cultural realms: “Indeed it seems to me that the differences are as interesting as the similarities, and I would like to urge a broad and flexible view of evolutionary theories of change” (Nelson, 2007, p. 92).

But in part the critique of an over-reliance on the principles of VSR has also claimed that Generalised Darwinism is too abstract and too ‘top down’. While Hodgson and Knudsen (op cit) acknowledge that there are significant differences between biological and economic systems, they argue that the differences relate to domain-specific details rather than to the general principles propounded by Generalised Darwinism. In other words, details that are specific for the economic domain are to be added to the three principles in order to get fully-fledged causal explanations of economic evolutionary processes. The problem with this position, as Vromen (2007, 2008) points out, is that if the three basic tenets of Generalised Darwinism are still to be necessary for explaining economic evolution but free of any biological connotation or analogy, then the form of Generalised Darwinism invoked will have to be of a very high level of generality and abstraction indeed. Yet this then means that even more ‘domain-specific’ hypotheses have to be added than Hodgson and Knudsen envisage in order to arrive at detailed causal theories of how economic systems evolve.

In this view, as the neo-Darwinian principles of VSR are forced to become ever more abstract in order to apply across all aspects of the economy, so they lose their explanatory power in the process (Cordes, 2006). Similarly, Levit et al (2011) argue that Generalised Darwinism is too ‘top-down’, trying in vain to proceed from an abstract hull to auxiliary hypotheses about economic processes. Instead, they argue, a better research strategy might be a ‘bottom-up’ approach that starts with concrete details:

If so, the recommendation for evolutionary economics would be to focus on analyzing the huge variety of specific evolutionary processes in the economy at a concrete level, and only when explanatory progress has been made at that concrete level, to engage in a (bottom-up) discourse of how the complex set of specific hypotheses can be organized into a more coherent causal and functional structure (Levit et al, 2011, p. 559).

In their opinion, this approach - which obviously bears a close similarity with the methodologies of ‘appreciative theorising’ and ‘grounded theory’ – is the more appropriate one for deriving general principles with which to understand economic evolution.

To many economic geographers this call to engage with ‘concrete variety’ will feel rather like a rendezvous with an old acquaintance. The debate about

whether to start with concrete details or with abstract theory, and the potential dangers entailed in either approach, has a long history in economic geography. It is tempting to agree with Levit et al by arguing that we should adopt a ‘bottom up’ approach in evolutionary economic geography by first analyzing the “huge variety of specific evolutionary processes in the [spatial] economy at the concrete level”, and then seek to develop general principles and theory from this basis. In our view, however, the ‘bottom-up’ strategy recommended by these (reconstructed) evolutionary economists is not unproblematic, as it carries the danger of veering too closely towards an inductive approach that does little more than generate a welter of empirical studies that might claim to be ‘evolutionary’, and which my use ‘evolutionary’ terms and phrases, but which actually fail to advance the theoretical or conceptual foundations of an evolutionary perspective. This is not to dismiss Levit et al’s persuasive critique of Generalized Darwinism and its rather constricting set of principles. But we are wary that a ‘bottom-up’ research strategy alone would find enough conceptual direction and momentum to drive the coherent development of evolutionary economic geography. Although important, the accumulation of an increasing array of empirical case studies of the historical spatial development of specific industries and technologies is not of itself a guarantee that a coherent body of evolutionary economic-geographic theory or principles will emerge as a result. In any case, a ‘bottom up’ approach surely presupposes that we have at least *some* idea of what the ‘evolutionary processes’ we are seeking to analyse actually are. A ‘bottom-up’ approach - whether a form of ‘appreciative theorising’ (Nelson, 1995) or what is now becoming known in evolutionary economics as ‘history-friendly models’ (Castellacci, 2006; Malerba et al, 1999; Malerba, 2010) - based on the close empirical examination of concrete specific cases and trends, must almost inevitably involve the use of some sort of guiding theoretical principles or concepts, and these presumably will be evolutionary in nature. After all, if we are interested in economic evolution, it makes sense to think in ‘evolutionary’ terms, however loosely such ontological preconceptions are framed. We are doubtful that good inductive research, including even what might appear to be straightforward historical narratives of regional industrial-technological change, can ever be wholly ‘theory free’ or devoid of metaphorical constructions.

In other words, there is a continuing role for evolutionary metaphors and analogies, even in ‘bottom-up’ approaches, because such metaphors can guide the process of theorizing *and* empirical work. Evolutionary metaphors and analogies, in other words, can help us to conceptualise historical change, and guide the search for evolutionary processes. The purpose of an evolutionary perspective in economic geography, we would stress, is *not* in searching for direct and exact economic-geographic equivalents of biological processes. Rather, the value of an evolutionary perspective is as *a way of thinking*, in our case about the unfolding

and transformation of economic landscapes over time. Evolutionary ideas and concepts taken from biology, ecology or some other related discipline, may suggest principles that are more generic in nature, that have an interpretation and relevance in fields like economics and economic geography quite different from those in which they were first expounded.

To this end, it is important that we engage with the latest ideas and concepts emerging in evolutionary theory. And one such area where new ideas and principles are being forged is the new ‘developmental turn’ in evolutionary thinking as found in evolutionary developmental biology (EDB) and developmental systems theory (DST). EDB and DST do not reject or abandon the principles of VSR, but seek to embed them in a larger, more expansive repertoire of concepts and ‘organizing principles’ used to explain evolution, and thereby to create space for the role of other factors and mechanisms in shaping the process and pathways of evolution. Potentially, then, these new fields may offer a wider body of ideas for use in evolutionary economic geography, and perhaps may even assist with integrating the study of economic evolution with that of (uneven) geographical development. To begin to move towards this framework we next examine the ‘developmental turn’ that is currently underway in evolutionary theory.

3. The ‘Developmental Turn’ in Evolutionary Theory

Much has been written about how the neo-Darwinian Modern Synthesis entrenched a separation between evolutionary and developmental biology. Evolutionary biology has classically been concerned with phylogeny, the evolutionary history of organismal populations, drawing heavily on the population genetic formalism of the neo-Darwinian Modern Synthesis. Developmental biology, on the other hand, is concerned with ontogeny, with the origin and development of an individual organism through its life span. Reconciling the evolutionary science of VSR with the science of development has troubled biologists for decades. Over the past twenty years or so, however, increasing attention has been directed to integrating evolution and development as part of a search for what some have called a ‘New Synthesis’ (Endler and McLellan, 1988), others a new ‘Extended Synthesis’ (Pigliucci and Müller, 2010), and still others a new ‘epistemic space’ (Müller, 2007; Pigliucci, 2007; 2009; Weber, 2011).

As mentioned above, this synthesizing endeavour has found expression in two main research programmes, namely Evolutionary Developmental Biology (EDB), and Developmental Systems Theory (DST).⁴ Of these, EDB is the more

⁴ The discussion that follows can only provide a brief, simplified and non-technical overview of some of the main ideas and insights that characterise EDB and DST. We have endeavoured to identify the main ideas that may have relevance for evolutionary economic geography.

theoretically articulated, and is explicitly aimed at building on and extending the Modern Synthesis (Raff, 1996; Hall, 2003; Carroll, 2000; Laubichler and Maienschein, 2007; Müller, 2007, 2008; Fusco and Minelli, 2008). DST is less well formulated but more expansive in orientation, and has its roots in psychobiology and behavioural psychology (Oyama, 2000; Oyama, et al, 2001; Gray, 2001; Robert, Hall and Olson, 2001; Griffiths and Gray, 1994, 2005). Although these two perspectives have different origins, several recent papers have addressed the relationship between them and in general conclude that EDB and DST are essentially complementary (Robert et al, 2001; Jablonka and Lamb, 2002; Gilbert, 2003; Griffiths and Gray, 2004, 2005). Considered together, these two approaches embrace a number of key departures from the Modern Synthesis.

First, each advocates a much more *holistic* perspective on evolution, an approach that allows evolutionary and developmental processes to interact, both with each other and with the environment. This implies a systems-orientated view that goes beyond the ‘gene-centrism’ of the Modern Evolutionary Synthesis to allow several other factors, mechanisms and interactions to play an equally vital role in shaping the evolutionary process. In EDB this new (sometimes called ‘epigenetic’) approach to evolution focuses on aspects of an organism’s development that lead to adjustment when its environment or internal organization changes (Brakefield, 2006) (see Table 1). An explicit allowance is made for environmental induction, that is for environmental influences to impact on development and evolution (Müller, 2007). Central to this new focus is the interplay between the developmental features of *robustness* and *plasticity*, and how these processes themselves evolve (Bateson and Gluckman, 2011). In this respect, biologists view organisms as complex adaptive systems, the *robustness* of which is defined as the maintenance through time of an organism’s core purpose and performance or functionality despite environmental perturbation. Robustness does *not* mean that an organism or system remains completely unchanged in the face of disruptions or perturbations in its environment; rather some structural or other features may *need* to change in order preserve *core* functions:

Robustness is often misunderstood to mean staying unchanged regardless of stimuli or mutations, so that the structure and components of the system, and therefore the mode of operation, are unaffected. In fact, robustness is the maintenance of specific functionalities of the system against perturbations, and it often requires the system to change its mode of operation in a flexible way. In other words, robustness allows changes in the structure and components of the system owing to perturbations, but specific functions are maintained (Kitano, 2004).

Robustness, therefore, may require and involve, *plasticity*, which describes an organism’s or entity’s malleability, its capacity to change or adapt its form or behaviour in response to changing external or internal conditions. Plasticity

involves developmental ‘reaction norms’ that relate the response of an organism’s internally coded, inheritable information (its genotype) to a particular environmental perturbation or system input. As West-Eberhard (2005, p. 6547) puts it: “I consider genes followers rather than leaders in adaptive evolution... We forget that... environmental factors constitute powerful inducers and essential raw materials whose geographically variable states can induce developmental novelties as populations colonise new areas”. In this account, new traits may appear for a variety of reasons (including environmental induction, and learning) and give rise to novel organismal forms and behaviours. If the novelty is advantageous, and affects the organism’s fitness, natural selection ‘fixes’ it by stabilizing the alteration of the genetic architecture (the genetic frequencies that make populations). Thus plasticity is not necessarily the opposite of robustness, or the closely related idea of developmental *canalization*, whereby organisms remain on their developmental pathways regardless of the variability in their environment, or at least up to certain degrees of environmental disruption. Further, robustness - the maintenance of certain core functions or performances - is often generated by plastic mechanisms, and plasticity is often regulated by robust mechanisms. It is the interplay between developmental robustness and developmental plasticity that shapes the pace and direction of evolutionary change.

Table 1: Some Key Concepts in Evolutionary Developmental Biology (EDB)

Concept	Main Focus or Definition
Robustness	Ability of an organism or system to maintain certain functionalities when subjected to substantial environmental or internal perturbation or disruption, and may involve or necessitate changes in the structure or components of the system
Plasticity	Ability of an organism or system to adjust its behaviour, function or form in response to mutations and environmental disturbances and disruptions
Niche Construction	Ability of an organism to modify, shape or control its own immediate environment so as to ensure its own evolutionary success
Evolvability	The capacity of a developmental system to evolve, which is primarily a function of its ability to generate variation in form in a way that potentially enhances survival and reproduction

Source: Müller (2007), Pigliucci and Müller (2010), Bateson and Gluckman (2011).

According to plasticity theory, then, environmental factors can elicit innovation through their direct influence on developmental systems (see also Reid, 2007). But at the same time, the environment does not simply set a problem to which the organism has to find a solution: an organism can often do a great deal to

create an environment to which it is best suited. Many organisms change the physical or social conditions with which they (and their descendants) have to cope. These ideas are now referred to as *niche construction* theory (Odling-Smee, 2010). Virtually all organisms modify their immediate environments to some degree, and in many cases such impacts sum up across individuals to affect the evolution of their descendants. The evolution of organisms is now viewed as depending on natural selection *and* niche construction. Adding niche construction to evolutionary theory connects evolution to ecosystem-level ecology (Odling-Smee, 2010), and contributes to an ‘eco-evo-devo’ relationship by introducing a recursive dynamic interaction between environment and organisms and thence populations.

This ‘developmental challenge’ to the neo-Darwinian Modern Synthesis is taken further within DST (Table 2). For most DST-theorists, what changes over evolutionary time is a *developmental system*, consisting of the organism *embedded in a broader ‘developmental context’*, much of which would traditionally have been regarded as an external (and autonomous) ‘environment’ (Griffiths and Gray, 2005). In DST, genes must be deeply contextualized. As Oyama (2000), a leading exponent of DST puts it, “if development is to re-enter evolutionary theory, it should be development that integrates genes into organisms, and organisms into the many levels of the environment that enter into their ontogenetic construction” (p. 113). In this task of *deep contextualisation* the ‘developmental system’ is the key construct, defined as the dynamic set of all of the interacting entities and influences on development at all levels, including the molecular, cellular, organismal, ecological, social and biogeographical (Oyama, 2000).⁵ This interactive matrix of entities and resources is seen as contingent and possibly spatio-temporally discontinuous, multilayered and relational. This view implies that clear distinctions between organism and environment cannot be sustained, and emphasises several additional key principles (Table 2).

First, the developmental importance of nongenetic factors implies a model of *multiple and dispersed systemic causality*. Causality does not reside in any one particular entity or class of entities but rather in the relations between developmental ‘interactants’. DST advocates a *constructionist interactionism* in which the outcomes of different types of causes are interdependent and Spatially and temporally contingent. This refocuses developmental inquiry on a multitude of factors, forces and mechanisms, without insisting that genes are ontogenetically

⁵ The adoption by DST of this much more inclusive vision of the components and limits of the development system, than that found in EDB, is a key difference between the two approaches. In DST, *aspects of the environment are a product of evolution as well as a cause of evolution*.

Table 2: Some Major Tenets of Developmental Systems Theory

Developmental System as Unit of Evolution	Developmental system consists of the organism embedded in a broader developmental context, all of which is subject to evolutionary processes. Evolution is not a matter of organisms or populations adapting to their environments, but of organism-environment systems co-evolving over time.
Deep Contextualisation	Defined as the dynamic set of all of the interacting entities and influences on development, at all levels.
Constructionist Interactionism	Development is the product of multiple interacting causes. No single source of influence has central control over an organism's development. The significance of any one causal process is contingent upon context and the state of the rest of the system: time and space matter.
Contingent Developmental History	Development is spatially and historically contingent, shaped by interactions among causal antecedents and inherited resources.
Extended Inheritance	The process of reconstruction, at each generation, of the developmental process through the nonlinear interactions among inherited developmental factors. This constructive process is autocatalytic and self-organising.
Emergence	Development is a process of emergence, whereby the organismal or systems forms at one level emerge from interactions of components at lower levels, and with their environment, but are not simply reducible to those components. Environment is a major generator of emergent evolutionary novelty, whereas natural selection engenders stasis
Self organization	Pattern and order emerge from the interactions of the components of a complex system without explicit directive instructions, either in the organism itself or from the environment. Self-organization involves processes that by their own activities change themselves.

Source: Oyama et al (2001); Robert et al. (2001), and others

or ontologically primary: no one single source of influence has central control over an organism's development. Evolutionary change results from the constructive interaction between all developmental resources: the various elements of developmental systems co-evolve. As noted above, organisms are not independent of or just passively dependent on their environments; they actively construct their developmental niches which are an integral part of the whole developmental system. This introduces new resources for variation and innovation, beyond mutation and recombination, and points to the ways in which developmental processes situated in their ecological niche can produce novel organismal forms

and behaviours. A further principle is that of *contingent developmental history*. DST emphasises the contingent and historical nature of developmental processes so that time and space matter. The key idea here is that the constellation and characteristics of any developmental system should be explained by the prior interactions between a range of causal antecedents. Interactions and learning at one stage of development are often critical to what happens in subsequent stages. In this way contingent experiences and resource changes can have long-lasting effects. At the same time, however, DST emphasises that both predictability and stability occur within developmental history. That is, despite the importance of contingent events, developmental systems also are marked by the repeated assembly of patterns of interaction. Evolution selects those developmental systems that reliably assemble all the necessary resources for the fulfillment of their life-cycle.

A third feature of DST is its *extended version of inheritance*. EDB itself operates with a wider model of inheritance – epigenetic inheritance – than that found in the Modern Synthesis. In the latter, the gene is the sole unit of hereditary transmission. The genetic-developmental network and the phenotype it generates are not inheritable, and hence cannot be a unit of evolution. In epigenetic inheritance theory, information transfer can take place between organisms, through social learning, through symbolic communication and through the interactions between the individual and its environment that are involved in niche construction. The inheritance of developmentally induced and regulated variations is recognized as important. DST-theorists go further, and move to a concept of ‘expanded inheritance’ by replacing the notion of transmission with the notion of the reproduction of developmental resources and interactions in successive generations (Griffiths and Gray, 2001). As a consequence, for DST-theorists the notion of ‘replicator’ is not used to refer to special factors able to produce reliable copies of themselves, but to designate the process of *reconstruction*, at each generation, of the developmental process through the interactions among inherited developmental factors.⁶

Fourth, both EDB and DST destabilize the selection-centred framework of modern evolutionary theory and place greater emphasis on the idea of *emergence*. In the Modern Synthesis, the problem of innovation was treated as part of the variation issue by calling all change in form ‘variants’. Accordingly, morphological novelties were seen as ‘major variants’. In EDB and DST, innovation and novelty are not treated in the same way as variation. EDB adopts a systems-orientated view of innovation (‘epigenetic innovation theory’), in which novelty origination is not based on the continuous variation of pre-existing characteristics, but appears

⁶ This extended view of inheritance has not gone uncontested by other evolutionary theorists. However, DST-theorists have argued that such critiques misunderstand this approach to development and evolution (see Griffith and Gray, 2005).

de novo from developmental system reactions. Thus novelty is a product of interactive emergence during the process of development.

Emergence also figures in the evolutionary development of organisms and other complex systems in another way, namely, in its association with *self-organisation*, that is the process in which order, pattern and structure at a higher-level of an organism or system *emerges* solely from numerous interactions among lower-level or subunit components making up that organism or system (Camazine et al, 2003). Moreover, the rules and processes specifying interactions among the system's components are executed using only local information, without reference to the macro-level pattern or to the organism's or system's environment. The subunits in biological systems acquire information about the local properties of the system and *behave* according to particular genetic programs that have been subjected to natural selection. This adds an extra dimension to self-organization in biological systems, because in these systems selection can finely tune the rules of interaction. By tuning the rules, selection shapes the patterns that are formed and thus the products of group activity can be adaptive. Self-organization involves processes that by their own activities change themselves. The greater the role of self- organization in the generation of life's adaptive order, the less the creative role of cumulative selection and the less the overall evolutionary process can be strictly termed 'Darwinian' (Edelmann and Denton, 2007).

What is obvious from this (necessarily brief and non-technical) survey of EDB and DST, is that evolutionary theory is moving beyond the neo-Darwinian Modern Synthesis. This makes debates about the applicability of Generalised Darwinism to both evolutionary economics and evolutionary economic geography too restrictive. As Depew and Weber (1995) have argued in a more general context, the 'developmental turn' underway in evolutionary biology should be a warning to all social scientists interested in constructing their own evolutionary approaches based upon only natural selection analogies:

These reflections suggest that it should be at least a mild constraint on any evolutionary theory that claims to explain human phenomena that it should throw light on, rather than eliminate or reduce away, the interactional, relational, intentional, and symbolic features that interpretative social scientists have already discovered about social reality. Perhaps it is not too much to say that what we need is an evolutionary theory worthy of the best social theory, not a social theory trimmed to fit a rapidly receding, overly simplistic evolutionary theory (Depew and Weber, 1995, p. 495)

So what then, might be gained by thinking through the implications of this 'developmental turn' in evolutionary theory for evolutionary economic geography? Are the ideas advanced by the new developmental approach to evolutionary theory useful in some way to our discipline?

4. A Developmental Turn in Evolutionary Economic Geography?

The first implications are ontological and epistemological. To date, evolutionary economic geography has tended to focus on the micro-level of the firm, on the spatial evolution of the population of firms that make up a particular industry: in short it has been mainly concerned with the construction of a sort of ‘evolutionary industrial geography’ rather than an explicit evolutionary theory of uneven regional development. There have been studies of how particular industries have evolved across space; studies of the evolution of one or more industries in a given place (such as a cluster or industrial district); and studies of the evolving geography of technological innovation by firms (including knowledge networks). Such studies have proved highly informative, and have yielded valuable insights. What has been much less in evidence is a concern with the synergy of different economic processes and structures in particular places and with the systemic tendency towards uneven regional development. Hence evolutionary economic geography has struggled to connect micro-scale processes with large-scale processes, patterns and regularities (Storper, 1997). The primary implication of the ‘developmental turn’ in evolutionary theory is that we need to move to a *more systemic and holistic* understanding of spatial economic evolution, one which considers not just industrial evolutionary dynamics, but the wider economic, institutional and socio-political structures produced by and constitutive of uneven geographical development (Table 3).

This in turn suggests that the typical focus (implicit if not explicit) in evolutionary economics and evolutionary economic geography on sets or bundles of rules and routines (typically interpreted as technologies or competences) as the basic ‘units of variety’ and the ‘units of selection’ might be incorporated into a more expansive focus on *economic developmental systems*. Dopfer (2005) suggests an ontology for evolutionary economics based on a model involving three ‘scales’ or levels of abstraction, those of micro, meso and macro rules, moving epistemologically from the former to the latter. We also envisage an ontology based on a multi-level abstraction, but of nested, interacting and co-evolving spatial-economic developmental *systems*, rather than simply units defined by rules or routines.⁷ Economic developmental systems are complex systems, and come in different forms and scales: workers and households, firms, industries,

⁷ Of course, it might be argued that everything in the socio-economy consists of, or can be reduced to, ‘rules’ and routines’ (some institutional theorists subscribe to this view). But to our mind, to reduce a complex system like an economy to rules and routines is akin to the problem of gene-centrism that the proponents of evolutionary developmental biology and developmental theory are seeking to avoid.

production networks, supply chains, clusters, cities, regions and nations are all types of (interconnected) economic developmental systems, all evolving over time through the interaction of their constituent developmental systems, and their co-interaction and co-evolution with their respective ‘environments’, that is other developmental systems of which they are themselves a component. No one ontological level takes precedence: there is no priority of the micro over the macro, or vice versa. And defining the nature and ‘boundaries’ of the developmental systems that make up the economy, and how they interrelate, may not be straightforward. Economic developmental systems are spatially distributed but also spatially discontinuous, have fuzzy boundaries, and are not easy to separate from their ‘environment’: these are precisely the features found in many complex systems which are neither completely closed nor entirely open (see Martin and Sunley, 2007).

Integral to a more holistic and systemic approach, and the layered multi-scalar ontology it involves, is the need for evolutionary analysis to engage in *deep contextualization*. That is to say, evolutionary accounts in economic geography should consider the full set of entities, factors and influences, including internal (endogenous) and external (exogenous), local and non-local, and structural and contingent, that have conditioned and shaped the evolutionary dynamics and trajectory of the spatial economic developmental system under study. This requires analysis ‘downward’, to micro-level processes including where appropriate, the role, decisions and purposive behaviour of individual key agents; ‘upward’ to take account of the meso- and macro-level circumstances and influences that might have constrained or facilitated a particular evolutionary path of the system in question; and ‘outward’, to consider the system’s and its components’ (firms’, workers’ and institutions’) connections with and dependencies on other systems elsewhere. This is not an appeal to some sort of ontological relativism, where everything that might impinge upon the evolutionary development of, say, a particular local or regional economy, has to be considered, or where no one factor is given more explanatory weight than any other. Rather, it is to argue that local and regional economies are complex, multi-layered systems, both connected to and in part also constitutive of their (competitive) environments, and that to understand fully their evolutionary development over time requires analysis of their multi-scalar and inter-dependent character.

Take the example of the firm. Firms are open and ‘deeply contextual’ developmental systems, comprising resources, activities and organizational forms, not just economic but also institutional, social and cultural. Firms are made up of interactions between several categories of phenomena including: physical and ecosystem resources; technologies; firm capabilities and organisation, industry structures; and institutions (including both markets and non-market regulatory, legal, financial and public institutions) (Nelson, 2011; Child et al, 2012). The

Table 3: Some Implications of the ‘Developmental Turn’ in Evolutionary Theory for Evolutionary Economic Geography

Implication	New/Additional Focus
Need for a more holistic and systemic ontology for evolutionary economic geography	<p>Moving from routines and rules as the basic units of variety and selection to the notion of multi-scalar spatial-economic developmental systems as the ‘units of evolution’</p> <p>Focus is on differential emergence, reproduction and adaptation of spatial economic developmental systems, and on the (co)evolution of their developmental pathways.</p>
Need for ‘deep contextualisation’ in evolutionary analyses	<p>Consideration of the whole set of influences and entities, internal and external, local and non-local, structural and contingent, that enter into the evolution of a spatial economic developmental system.</p> <p>This implies, where appropriate, analysis both ‘downwards’ (the role of agency and purposive behaviour), as well as ‘upwards’ and ‘outwards’ (the influence of socio-institutional structures and regulatory conditions impinging on the system under study)</p>
Need to view spatial economic developmental systems as self-organising entities with emergent properties	<p>Recognition that many spatial economic developmental systems are self-organising, arising out of the interactions between their components and their connectedness. This process is not directed or controlled by any agent or subsystem inside or outside of the system, although the path followed by the process, and its initial conditions, may have been chosen or instigated by certain (perhaps more influential) agents. Those same interactions can give rise to emergent properties and innovations that are not simply reducible to the individual components, and which then feedback to shape the evolution of those components</p>
Need to examine the degree to which spatial economic developmental systems can construct their own environments	<p>Consideration of the processes by which agents, firms and institutions do not simply react to their developmental, competitive and institutional environments but modify and even construct those environments (‘niches’) in their own favour. This demands an understanding of the power structures involved, and the regulatory and other conditions that both allow and obstruct these processes</p>
Need to operate with an extended view of the influence of inherited legacies (economic and institutional structures and practices) on the evolution of spatial economic developmental systems	<p>Appreciation of the formative role of path dependence across the set of components making up a spatial economic developmental system, where path dependence is construed as involving the adaptive reconstruction of the developmental process through the nonlinear and autocatalytic interactions among inherited developmental factors</p>
Need to account for and trace the implications of the robustness and plasticity of developmental paths	<p>Analysis of the processes making for robustness and/or plasticity of a spatial economic developmental system’s evolutionary trajectory in the context of constant or periodical changes in the system’s ‘environment’, and how robustness and plasticity influence the adaptive resilience of the system over time. This includes examining how critical stresses have long lasting impacts on resources and potential for future change</p>

mutual interdependence of these factors means that they show reciprocal causality. The concept of a developmental system also emphasises that the

competences and capabilities of firms are so strongly interpenetrated by exogenous ‘environmental’ factors, such as competitive pressures from rivals, collaborations with cognate firms, micro and micro-regulatory arrangements, and the like, that it is impossible to draw a clearly defined boundary around the firm. And while the evolution of a firm – in terms of changes in its technologies, its products, its labour inputs and its locational dynamics – obviously reflects imperatives arising from within, many such changes will be induced by pressures and opportunities arising in the firm’s ‘environment’. In addition, while some interactions and relationships that make up a firm will be local, others may be quite geographically remote so that the firm’s evolution will inevitably involve the assembly of spatially distributed networks and relationships at different scales. In this way, these ideas allow insights from relational economic geography and its focus on relationships and networks to be merged with an evolutionary understanding of firms.

Or consider the case of a business cluster, an archetypical example of a spatial economic developmental system. There has been growing interest in how clusters evolve (see *Regional Studies*, 2010; Martin and Sunley, 2011b; 2012). What has often been accorded insufficient examination is any proper contextualisation of cluster evolution both in terms of the role of agency in shaping what in reality can be quite heterogeneous, even divergent, developmental strategies by individual firms in a cluster, and in terms of the relationships of individual cluster firms with their respective external competitive and collaborative environments⁸: too often clusters are studied in isolation from the wider system of similar and related clusters of which they are both a part and with which they co-evolve.

A developmental, complex systems perspective on spatial economic evolution would also assign importance to explicating the roles of *self-organisation* and *emergence*. As we have argued elsewhere (Martin and Sunley 2007, 2012), self organization and emergence are key mechanisms in the evolution of economic landscapes. The idea of self-organisation is related to the notion of autopoiesis, which refers to the dynamics of a non-equilibrium system that produces the components which in turn continue to maintain the organised structure that gives rise to those components. The geographical forms that constitute the economic landscape – cities, centre-periphery patterns, clusters, industrial districts and so forth – can, in a certain sense, be viewed as emergent, self-organising phenomena. Cities, clusters, and regional economies arise out of the myriad individual actions and interactions of economic agents (firms,

⁸ Different economic agents and firms in an industrial cluster may react quite differently to changes in the market and technological environment in which they compete, and hence may pursue different developmental and evolutionary trajectories. Understanding this heterogeneity requires deep contextualization, ‘downwards’, ‘upwards’ and ‘outwards’.

workers, households, institutions, etc) that generate outcomes (daily behaviours, investment and employment decisions, knowledges, profits, incomes, and expenditures) that serve to reproduce those same spatial systems. But, in contrast to biological systems, where self-organisation is often regarded as a ‘spontaneous’ process, in the socio-economic realm the development of cities, clusters and spatial structures in general is the complex outcome of the *intentional* behaviours and learning of economic agents pursuing their own objectives. In so doing, some agents may possess and exert more influence and power than others over the precise form and function of spatial economic ‘self-organisation’.⁹ Thus the idea of ‘self-organisation’ in a evolutionary-developmental perspective on the economic landscape is necessarily a political economy one, in which the imperatives and logics of capitalist accumulation inexorably tend to ‘self-organise’ the economic landscape unevenly, but where the precise form of that unevenness will vary from place to place and over time, depending on the opportunities afforded in particular places and how economic actors respond to those opportunities. *Self-organisation in the economic landscape is quintessentially a power-inflected evolutionary process.*

Self-organisation in the economic landscape is closely bound up with various processes and forms of emergence. The idea of emergence is attracting increasing interest within economics (see, for example, *Journal of Economic Behaviour and Organisation*, 2012). Different economists interpret the notion in slightly different ways (see Harper and Lewis, 2012), but the basic idea is that emergence occurs when wholes (eg. the economy) form from, and take on properties and produce outcomes that differ from, and are not simply reducible to, the actions of and properties possessed by their constituent individual parts (human agents and organizations) (de Haan, 2006, p. 294). In economic geography, an good example of emergence is how the spatial agglomeration of economic activity – in cities or in business clusters – gives rise to various localised externalities that do not reside in firms themselves but become ‘macro-level’ features of the agglomeration as a whole, available to (that is, which have ‘downward causal influence’ on) those firms as sources of productivity gain and competitive advantage. Properties of the firms, and the interactions between the firms, become represented in and give rise to agglomeration-level system-type properties, especially externalities, which then exert influence on the performance of the firms concerned (see Table 4). A similar point was made by Massey (1992) when discussing the ‘politics of space/time’:

Spatial form as ‘outcome’... has emergent powers which can have effects on subsequent events. Spatial form can alter the future course of the very

⁹ Our conceptions of self-organisation and emergence thus differ from the use of these notions in Austrian economics, where they are ascribed to the ‘spontaneous’ workings of abstract competitive market forces.

histories that have produced it... One way of thinking about all of this is to say that the spatial is integral to the production of history... just as the temporal is to geography (Massey, 1992, p. 84).

Table 4: Types of ‘Downward Causation’ and some Spatial Economic Examples

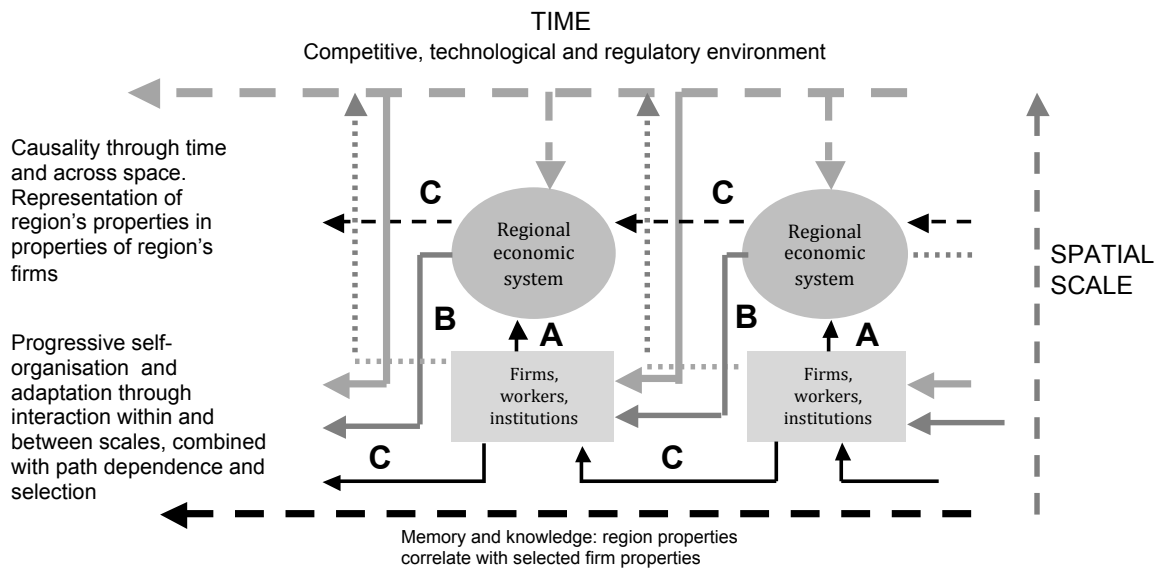
Type of Downward Causation	Examples off Spatial Economic Effects (eg in an agglomeration)
<p>Effects of system organisation Boundaries and patterns of organization of a system shape which causal powers of their constituent components are activated (or deactivated)</p>	<p>The spatial agglomeration of firms opens up local market niches and supplier opportunities for firms concerned. Though generally positive, such local orientation may also restrict the export reach of local firms</p>
<p>Effects of external system consequences Emergent impact of a system on its external environment influences properties and interactions of system components</p>	<p>A local cluster can shape the wider industry of which it is a part, and acquire an external reputation which in turn influences the resources available to its firms, their performance and market position</p>
<p>Effects of system-level dynamics Properties and constraints emergent at system level become internalised by system components</p>	<p>Conventions and practices may emerge at the agglomeration or cluster level which then become internalised in the routines and decisions of the constituent firms</p>
<p>Effects on generative processes Properties, processes and constraints emergent at system level alter selection pressures on, and hence sources of constructive variation in, lower level components</p>	<p>The form and degree of specialisation of a local agglomeration or cluster, and the nature of local competition and collaboration, may shape the scope for and direction of innovation among constituent firms</p>

After Martin and Sunley (2012)

Emergence is a source of innovative and evolutionary change, and is itself a dynamic, recursive process. It thus both shapes and reshapes the structural and organizational legacies that influence the historical evolution of economic landscapes. The emergence of various types of externalities through the spatial agglomeration of economic activity may shape the generation, viability and selection of new products and new firms within such spatial economic developmental systems. And these processes in turn reshape or reinforce the nature of the externalities arising from agglomeration. The recursive nature of this process involves the interaction between two key features of emergent systems, namely ‘memory’, or path dependence, and selection (Martin and Sunley, 2006, 2012) (see Figure 1). Path dependence effects occur through several mechanisms and across scales (firm, industry, spatial agglomeration or cluster, and external ‘environment’). Firm properties shape the properties of the regional economy or spatial agglomeration in question, which in turn influence firm properties. At the

same time, firms themselves carry over products and practices from one period to the next, whilst also embodying learning effects and knowledge spillovers arising from interactions with other local firms. And to the extent that a region's firms compete or collaborate with similar firms in other regions and locations, they influence their wider competitive and technological environment, which feeds back to influence the local firms' developmental trajectories. Further these processes will impact differently on different local firms, such that selection will occur, and the population of local firms will change as some cease to compete, decline and disappear, while new ones are created. *Path dependence, then, can itself be viewed as an emergent property of the economic landscape, while at the same time acting as a key mechanism by which the spatial forms of that landscape themselves emerge.* The issue, however, is how 'strong' that path dependence is, and what the relative roles are of low-level components (firms, institutions), and higher-level (regional) emergent forms and processes (see Martin and Sunley, 2006, 2012; Martin, 2010).

Figure 1: Evolutionary Emergence and Path Dependence in the Economic Landscape



- A - Morphological emergence of spatial agglomeration of firms, workers, institutions
- B - Emergence of agglomeration-level properties that influence existing firms and workers and attract new firms and workers
- C - Involves memory effects within firms and memory and selection effects arising at agglomeration and extra-region levels. Developmental-evolutionary path dependence

Source: Adapted and modified from Martin and Sunley (2012)

Of course, while the notion of evolutionary emergence appears to capture the recursive way in which economic evolution may operate, we need to bear in mind that there are also limits to the analogy between biological evolutionary emergence

and emergence in economic systems. In social and economic systems, both self-organisation and emergence typically arise from (power) relationships between individuals (Lawson, 2011; Sayer, 2010), and relationships are undoubtedly fundamental to many economic capabilities. In addition, socio-economic self-organisation and emergence are much more reflexive: agents are aware of the context in which they operate and seek to modify their behaviour as a consequence. This suggests that economic self-organisation and emergence will be essentially knowledge-based and knowledge-driven, and that we should be especially concerned with processes by which agents sample, select and build upon past and existing knowledges in particular locations (Foster, 2010).

5. Towards an Analytical Agenda: The Fusion of Economic Evolution and Development

Precisely how far this idea of a ‘developmental evolutionary economic geography’ can be taken, both conceptually and especially empirically, remains of course to be seen. It is not possible here to map out a detailed research programme. But we can offer some issues for future discussion. The analytical implication for evolutionary economic geography of the developmental turn in evolutionary theory we have outlined above is that by arguing that evolutionary economic geography should be made more contextual, developmental and holistic in orientation, the possibility is opened not only for embracing a more expansive set of evolutionary notions – extending our ‘analytical toolkit’ - but also for linking the approach more constructively to other perspectives or ‘analytical frameworks’ in economic geography, that is for engaging in epistemological pluralism. A fusion of economic evolution and development might release substantial analytical and empirical energy.

In making their influential case for evolutionary economic geography, Boschma and Frenken (2006) saw it as separate from but having interfaces with institutional economic geography on the one hand, and what they call Neoclassical economic geography on the other. We agree with the interface and connection with institutional economic geography. A developmental evolutionary economic geography would view institutions (at all scales), not only developmental systems in their own right, but as systems that permeate all other economic developmental systems, from households to firms to industries, to local economies and so on. Not only do institutions of all kinds and at all scales condition, constrain and enable the operation of evolutionary mechanisms in the economy, but these same institutions are themselves subject to similar such evolutionary mechanisms and processes: an economy and its institutional forms and arrangements co-evolve. *Institutions are both context and consequence of economic evolution.* How

institutions co-evolve with the economy is thus a key issue requiring analysis (Setterfield, 1998). How robust, plastic and adaptive are institutions? In what ways and how quickly do institutional forms adapt to changing economic conditions and circumstances? On the one hand, stability of institutional structures and arrangements is needed in order for economic systems to function and reproduce themselves: institutions serve to reduce uncertainty regarding future organizational, regulatory and related conditions. In David's (1994) words institutions are 'carriers of history' and act as a key means of extended economic inheritance and path dependence. Institutions help determine the balance between competition and co-operation and thus strongly shape the emergence of economic developmental systems across space (Martin, 2000; Nelson, 2006). On the other hand, institutional rigidities and dysfunctional institutional forms can hinder economic development. Institutions can hold back economic innovation and change. As a growing catalogue of evidence on recent institutional crises – from the global scale to the national to the local - indicates only too vividly, institutions can fail, and such failures can seriously destabilize economies.¹⁰ A developmental evolutionary economic geography would necessarily examine the co-evolutionary dynamics of institutions and the economic systems of which they are a part.

Boschma and Frenken suggest that the interface of evolutionary economic geography with Neoclassical location theory derives from a shared interest in the usefulness of formal modeling strategies: in other words, the interface is primarily a methodological one, since evolutionary economic geography, they argue, also employs modeling and quantitative techniques. While evolutionary economics, and some versions of evolutionary economic geography do indeed employ such techniques, for us the key connections between different perspectives in economic geography should first and foremost be conceptual and ontological, not methodological. On this basis, with its adherence to the assumption of equilibrium, its neglect of history, its decontextualised mode of abstraction, and its unrealistic model of rational maximizing human behaviour, Neoclassical location theory has little ontological relevance to evolutionary economic geography, or indeed to the real world of economic growth and development (this same criticism can be levied at the latest incarnation of neoclassical location theory, namely the 'new economic geography' – see Martin, 1999, 2011; Garretsen and Martin, 2010). If evolutionary economic geography is about improving our understanding of uneven geographical development, as we believe it should be, then the more

¹⁰ It is intriguing that the recent surge of interest by economic geographers in institutions comes at a time of mounting institutional failure and growing public disenchantment with, and distrust of, many of the institutions that govern everyday economic and social life. The financial crisis that has afflicted many countries in 2008 was in part the result of the failure of the regulatory institutions to curb the excessive risk taking and leverage activities of the banks.

appropriate interface and connection is with geographical political economy, given the latter's core focus on capitalism as a dynamic yet crisis-prone process of economic growth and development that is inherently spatially uneven. Now whether geographical political economy is superior to evolutionary economic geography, and whether it provides a more compelling explanation of economic evolution, as implied for example by Oosterlynck (2012) and Mackinnon et al. (2009), are claims that are themselves open to debate. Further, we suspect different economic geographers would in any case subscribe to somewhat different versions of what they regard as 'geographical political economy', and would not necessarily view the approach as synonymous with Marxist political economy (see Sheppard, 2011). There is no single unified, integrated or generally agreed form of geographical political economy, just as there is no one single unified version of evolutionary economics (Dopfer and Potts, 2004, p. 195), nevertheless, common themes of most versions of geographical political economy include an explicit focus on uneven development and an emphasis on 'large' systemic processes (such as regimes of accumulation, crises, etc) and 'big' structures (such as modes of regulation, the state, etc.). It is fair to say that, to date, evolutionary economic geography has given insufficient attention to such systemic processes and structures. Yet such 'big' processes and 'large' structures play key roles in shaping the processes, rhythms and directions of economic change (Tilly, 1984). The labour processes, wage relations, regulatory architectures and technological systems that make up an historical regime of capital accumulation, function to enable, constrain and influence the dynamics and interaction of the various developmental systems (firms, industries, labour markets, institutions, regional patterns of development) that make up (the space economy of) that phase of capitalism. For instance, the dynamics of capital investment in particular industries and the ways in which these shape demand for other industries are fundamental to the process of adaptive structural growth (Metcalf et al, 2006). Likewise, the forms of state-economy relations, economic governance structures, and political institutions that define the mode of regulation associated with a particular regime of accumulation also condition the scope and pace of evolutionary change in the economy. As such, some of the core ideas that underpin geographical political economy could certainly inform and enrich evolutionary economic geography, and provide a more systemic and holistic orientation to our analyses.

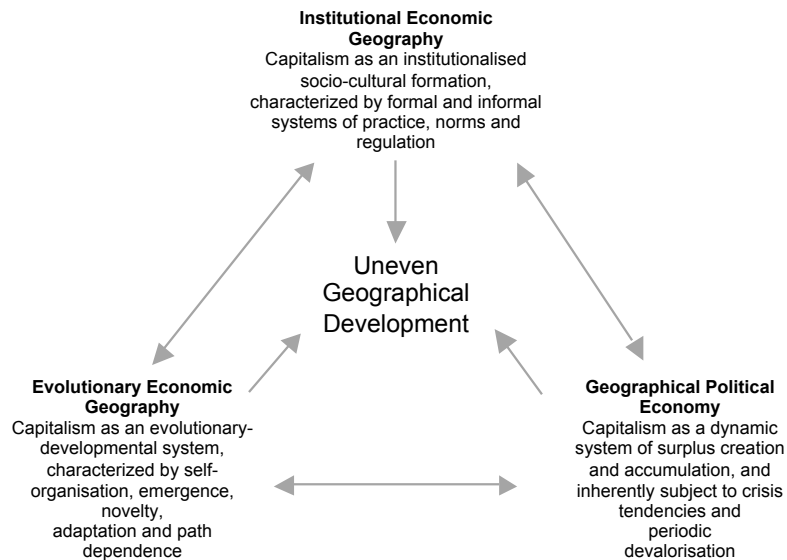
But equally, the processes and mechanisms of economic evolution shape the dynamics and trajectory of capitalist development. The 'big' processes and 'large' structures of capitalism are more than just the aggregates or 'averaged sums' of the micro-changes and parts (firms, institutions, workers, spatial structures, etc.) on which they based. They are also emergent in nature (Foster, 2010). In the context of capital, emergence pertains to the dependence of system

properties at various levels (scales) in the capital structure on the mode of composition and organization of lower-level elements in that structure. Emergence occurs at each level of the capital structure where elements are connected to form new systemic ‘wholes’ (eg capital goods, firm-level capital combinations, industry level structures, and spatial patterns and structures of various kinds), and those ‘wholes’ take on properties that are not simply reducible to the elements of which they are composed. Thus industry-wide capital structures though synchronic with, cannot simply be reduced to, the capital combinations of individual firms. Further, and importantly, the interactions between processes occurring at all scales of the capital structure – within firms, between firms, within and between industries, and within and between places - give rise to diachronic emergence or the appearance of novel systemic properties that shape the evolution of an economy over time. Emergence is ubiquitous in the economic landscape, and occurs every time there is an appearance of a qualitatively new good or service, technology, design, firm, network, market or industry. Emergence is key to understanding uneven geographical development and its evolution over time.

In short, evolutionary economic geography, institutionalist economic geography and geographical political economy should not be seen as competing alternative paradigms, but as complementary perspectives each capable of informing the other (Figure 2). Each perspective – evolutionary economic geography, institutional economic geography and geographical political economy – sees capitalism through a different lens, each emphasizing different particular features, structures and processes. Yet they also overlap, and can help inform one another. Both institutional economic geography and geographical political economy can assist in the ‘deep contextualization’ we have argued is necessary in evolutionary economic geography. Institutional forms and practices (from individual social-cultural norms, to social networks, to the state) on the one hand, and ‘big’ systemic processes and structures, such as regimes of capital accumulation, modes of regulation, and crisis tendencies, on the other, influence and condition the mechanisms of economic evolution and their spatial outcomes. In turn, those evolutionary mechanisms shape the formation and reformation of institutional arrangements and the nature and dynamics of capital accumulation. Economic evolution and economic development should be seen as inextricably intertwined: nothing makes sense in economic geography except in the light of evolution *and* development.

The ideas central to a new ‘developmental’ evolutionary economic geography - robustness, plasticity, self-organisation, emergence and evolvability – should not, therefore, be seen as antithetical to geographical political economy, but as

Figure 2: Multiple-Perspectives in Economic Geography: Towards a Synthesis?



helping to shed new light on how the process of uneven regional development plays out across economic landscapes. According to Harvey (2006) the ‘coercive laws’ of capital accumulation and competition produce perpetual instability within the geographical landscape of capitalism:

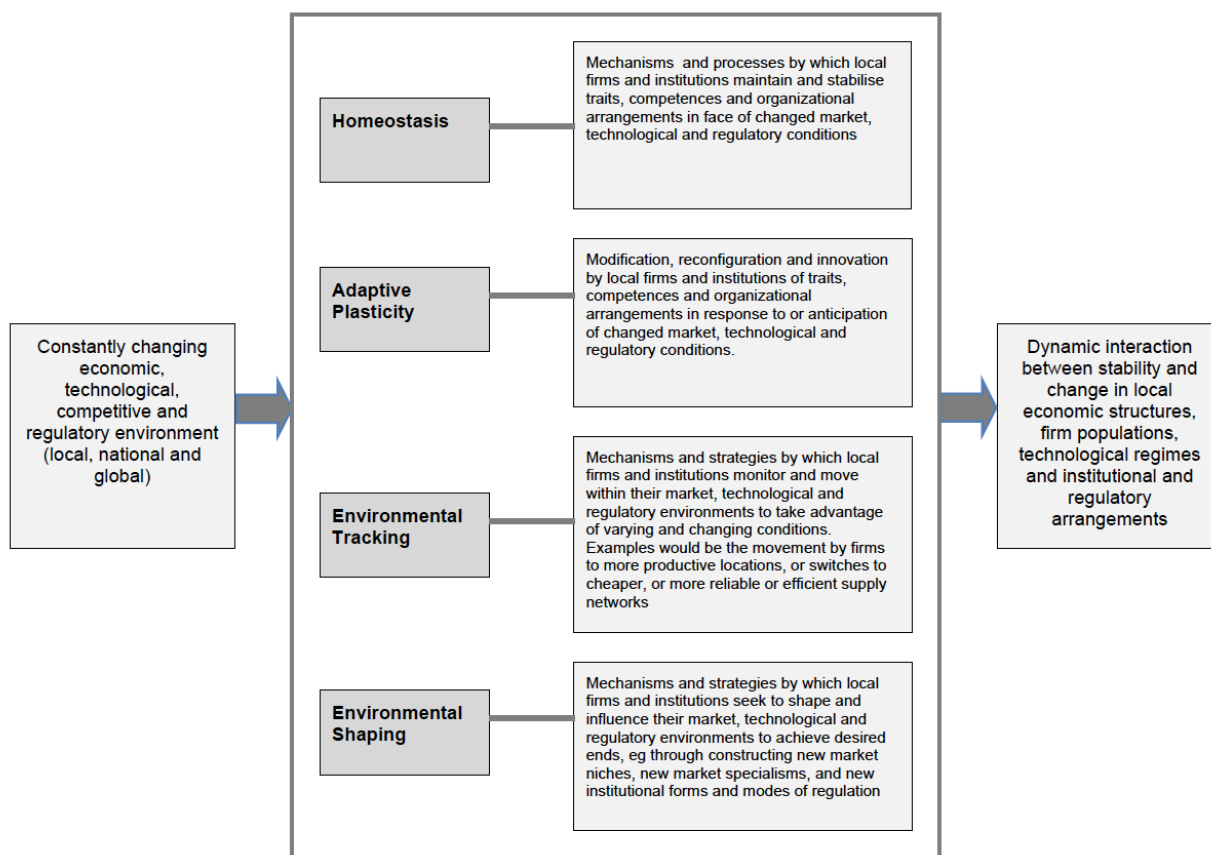
capitalism is about growth not stationary state equilibrium. The problem is to see how spatially confined market structures evolve in relation to both growth and technological dynamism.... Capitalist producers in competition with each other seek to gain advantage and higher profits by adopting superior technologies and organizational forms... But the search for excess profits generates a locational dynamism within production that parallels technological and organizational dynamism. Trade-offs exist between these two ways of gaining competitive advantage... The coercive laws of competition nevertheless produce perpetual instability within the geographical landscape of capitalism (pp.97-98).

Evolutionary concepts can help explain this instability and the spatial forms it produces; why some firms and places are more or less ‘robust’ to the ever-shifting pressures of competition; why some firms and places are more able to adapt (are more ‘plastic’); and why some firms and places are more able to initiate technological and organizational change than others (ie. why evolvability varies across firms, industries and places).

Take for example, the concept of robustness. The notion of robustness, recall, is not about stasis or the preservation of existing functions and structure in the face of perturbation or change (whether arising from within or without), but about the capacity of a system such (as a local economy) to *maintain core functionality and performance* (say economic growth, and full employment and rising real incomes for its residents) – under conditions of a constantly changing

(competitive and technological) environment. The recent evolutionary developmental biology literature identifies four different pathways to robustness in the face of perturbations in natural systems: homeostasis, adaptive plasticity, environment tracking, and environment shaping (see, for example, Whitacre, 2012). First, *homeostasis* refers to the stabilizing regulation of internal system states which buffers stresses through altered uses of components in order to preserve viability. Second, *adaptive plasticity* modifies traits in order to regulate responses to a changing environment, and often involves context-dependent changes in the function and structure of networks. Both of these two types of response can occur through reorganization or forms of self-organization that experiment with solutions. Third, *environment tracking* maintains stability through either temporal or spatial movement, which may be to avoid threatening conditions or to maintain the acquisition of key resources. Fourth, *environment shaping* involves controlling and shaping the environment through co-evolution, inheritance, and niche construction with the aim of creating more amenable conditions and reducing system vulnerabilities. It may be helpful to begin to approach economic robustness and resilience by envisaging economic equivalents of these types of pathway (Figure 3).

Figure 3: Pathways to Local Economic Robustness



For instance, homeostasis through altered use of components and feedback controls on economic processes is a basic type of response used by firms to economic changes. Yet this appears to be a limited and incremental type of response, which may not be sufficient to cope with more fundamental changes. It may well lead over time to 'lock-in' and increased vulnerability to more profound negative shocks. *Adaptive plasticity*, on the other hand, involves the modification of routines, practices and activities either through feedback and regulation or through processes of internal reorganization and self-organization. The functions of economic networks may be just as context dependent as those in biology, so we need to examine how inter-firm networks, industrial–technological paths and institutional structures adjust and adapt with changing economic conditions (Strambach, 2008; Vissers and Dankbaar, 2013). This type of economic plasticity allows a wider range of responses and could include or generate radical process innovations. *Environment tracking* would involve relocation of firms to other locations – an example of Harvey's 'locational dynamism' - which, of course, has been widely seen in labour intensive assembly firms that move overseas to take advantage of cheaper wages or a more pliant workforce. Alternatively, it could involve a switch in market focus to maintain the viability of certain products.

However, the *environment shaping* route to robustness is probably the most important in economic terms as it involves a very broad range of strategies including marketing and advertising, creating new markets or market niches through technological innovation (Harvey's 'technological dynamism'), and the production of human and business ecosystem resources. Collaboration with universities and technical institutions in order to construct a skilled or expert labour supply is a good example. One fundamental form of environment shaping involves co-evolution, for example where economic systems and their 'natural' environments shape each other (Norgaard and Kallis, 2011). Over the long term we might expect economic resilience to depend heavily on the degree to which environment shaping activities by firms are successful, rather than inadvertently dysfunctional and leading to a long term loss of adaptability. In any spatial economic developmental system these different forms of response by firms will be combined in various ways, and their relative prevalence may determine whether and to what extent an economic system proves adaptive and resilient. A firm pre-occupied with homeostasis will restrict its potential for environment shaping so that spin-offs are created precisely to experiment with market shaping activities. Structural and macro-economic changes will also be influenced by these types of strategic choices. A developmental evolutionary economic geography would seek to understand the institutional and cultural contexts that shape these types of decision-making and pathway.

Ultimately, economic development is about the capacity of an economic system – be it a firm, an industry or a local economy – to adapt over time in response to or anticipation of changing market, technological and regulatory conditions and opportunities. How such adaptability arises, the forms it takes and the direction(s) it assumes, all help shape the ‘big processes’ and large structures’ of capitalist development, and those big processes and large structures in turn stimulate and condition the process of adaptive growth. The notion of economic robustness may be a useful organizing principle by which to investigate the process of economic adaptation. A key empirical research focus in a more developmental inflected evolutionary economic geography could thus be why it is that different robustness strategies tend to emerge and dominate in different firms, industries and places, and why some firms, industries and places exhibit greater adaptive plasticity than others.

6. A Concluding Note

Our aim in this paper has not been to undermine what evolutionary economic geography has thus far achieved. To the contrary, our argument has been for a widening of the conceptual apparatus of evolutionary economic geography so as to ensure that apparatus reflects current thinking and discussion in evolutionary theory. For, whether the objective is to construct a distinct paradigm of evolutionary economic geography, or to infuse evolutionary ideas into existing perspectives, the evolutionary concepts and metaphors we use and drawn upon should reflect the latest thinking and debates in evolutionary theory itself. Furthermore, it is our belief that the overarching aim of evolutionary economic geography should be contribute to our understanding of geographically uneven development. Within evolutionary biology - a major source of the Darwinian-inspired ideas frequently used in evolutionary economics and evolutionary economic geography - a significant reappraisal, extension and reorientation is underway, what we have termed a major ‘developmental turn’, as found in Evolutionary Developmental Biology (EDB) and Developmental Systems Theory (DST). These two new streams of evolutionary thinking are not only leading to a reconsideration of the three key tenets of neo-Darwinian evolutionary theory – variety, selection and retention (VSR) - but are also beginning to reveal how the processes of evolution and development in biological systems are inextricably interrelated. In so doing, a whole range of new concepts, principles and mechanisms are being explored and elaborated. These may have suggestive implications for how we might think about economic evolution in general and about the evolution of the economic landscape more specifically. While some of

these concepts and principles, such as self organization and emergence, have begun to find their way in the writings of certain economic geographers, our own included, those discussions (and very definitely our own!) have thus far been rudimentary; and other ideas found in EDB and DST, such as robustness, plasticity, niche construction and evolvability have yet to be examined at all for their potential usefulness. And, most importantly, the focus in EDB and DST on holistic and deeply contextualized accounts is also suggestive for evolutionary economic geography.

We are not suggesting here that the three basic neo-Darwinian evolutionary concepts of VSR are redundant or that they should be jettisoned: far from it. But the dual message of evolutionary development biology and developmental system theory is both that these three principles need reappraisal and that several other key metaphors may help to shed valuable light on how local, regional and urban economies evolve. We would urge evolutionary economic geography to embrace this message rather than staying put on its familiar conceptual terrain. Of course 'evolution' and development', and notions such as selection, robustness, self-organisation, plasticity, emergence, and so on, mean different things in the socio-economic realm as compared to their counterparts in the biological-natural: our use of metaphors taken from the latter must be carefully re-interpreted when put to work in the former. But non-trivial and tendentious though this task is, it could repay investigation. Further, the 'developmental turn' in evolutionary theory, we contend, serves as a metaphor in its own right, in the sense that it implies that evolutionary economic geography could follow suit with its own 'developmental turn', and seek to integrate ideas on economic *evolution* with ideas on economic *development*. Moving towards that goal is a second reason for extending the conceptual foundations of evolutionary economic geography, in order to focus it more directly on the issue of geographically uneven development, which we take to be a fundamental concern for our discipline.

References

- Aldrich, H., Hodgson, G., Hull D., Knudsen, T. Mokyr, J. and Vanberg, V. (2008) In defence of Generalized Darwinism, *Journal of Evolutionary Economics* 18, pp. 577-596.
- Asheim, B., Boschma, R. and Cooke, P. (2011) Constructing Regional Advantage: Platform Policies based on Related Variety and Differentiated Knowledge Bases, *Regional Studies* 45, 7, pp. 893-904.

- Barnes, T. and Sheppard, E.S. (2010) 'Nothing includes Everything': Towards Engaged Pluralism in Anglophone Economic Geography, *Progress in Human Geography* 34, 2, pp. 193-214.
- Bateson, P. and Gluckman, P. (2011) *Plasticity, Robustness, Development and Evolution*, Cambridge: Cambridge University Press.
- Boschma, R. (2004) Competitiveness of regions from an evolutionary perspective, *Regional Studies* 38.9, pp. 1001-1014.
- Boschma, R. and Frenken, K. (2006) Why is Economic Geography not an Evolutionary Science, *Journal of Economic Geography*, 6, pp. 273-302.
- Boschma, R. and Frenken, K. (2009) Some Notes on Institutions in Evolutionary Economic Geography, *Economic Geography*, 85, pp. 151-158.
- Boschma, R. and Martin, R. L. (2007) Constructing an Evolutionary Economic Geography, *Journal of Economic Geography*, 7, pp. 537-548.
- Boschma, R. and Martin, R.L. (Eds) (2010) *Handbook of Evolutionary Economic Geography*, Chichester: Edward Elgar.
- Brakefield, P. M. (2006) Evo-devo and Constraints on Selection, *Trends in Ecology and Evolution* 21, 362-368.
- Buenstorf, G. (2006) How Useful is Generalized Darwinism as a Framework to Study Competition and Industrial Evolution? *Journal of Evolutionary Economics*, 16, 511-527.
- Camazine, S., Deneubourg, J.L., Franks, N.R., Sneyd, J., Theraulaz, G. Bonabeau, E. (2003) *Self Organisation in Biological Systems*, Princeton: Princeton University Press.
- Campbell, D.T. (1965) Variation and Selective Retention in Sociocultural Systems. In H.R., Blanksten, G.I. and Mack, R.W. (Eds) *Social Change in Developing Areas: A Reinterpretation of Evolutionary Theory*, Cambridge, Mass: Schenkman, pp.
- Carroll, R.L. (2000) Towards a new evolutionary synthesis, *Trends in Ecology and Evolution* 15, 1, pp. 27-32.
- Castellacci (2006) A Critical Realist Interpretation of Evolutionary Growth Theorizing, *Cambridge Journal of Economics*, 30, pp. 861-880.
- Chakravarthy, B. (1982) Adaptation: A Promising Metaphor for Strategic Management, *Academy of Management Review* 7, 1, pp. 35-44.
- Child, J., Rodrigues S. and Tse, K. (2012) The dynamics of influence in corporate co-evolution, *Journal of Management Studies* 49, 7, pp. 1246-1273.
- Cochrane, T. and MacClaurin, J. (2012) Evolvability and Progress in Evolutionary Economics, *Journal of Bioeconomics*, 14, pp. 101-114.
- Coe, N. (2011) Geographies of Production, 1: An Evolutionary Revolution? *Progress in Human Geography*, 35, pp. 81-91.

- Cooke, P. and Eriksson, A. (2012) Resilience, innovative 'white spaces' and cluster platforms as a response to globalization shocks, Chapter 2 in P.Cooke, M. Parrilli and J. Curbelo (Eds) *Innovation, Global Change and Territorial Resilience*, Cheltenham: Edward Elgar, pp. 43-70.
- Cooke, P. and Morgan, K. (1998) *The Associational Economy: Firms, Regions Innovation*, Oxford University Press.
- Cordes, C. (2006) Darwinism in economics: from analogy to continuity, *Journal of Evolutionary Economics* 16, pp. 529-541.
- David, P. (1994) Why are institutions 'the carriers of history': Path dependence and the evolution of conventions, organizations and institutions, *Structural Change and Economic Dynamics* 5, 2, pp. 205-220.
- De Haan, J. (2006) How Emergence Arises, *Ecological Complexity*, 3, pp. 293-301.
- Depew, D.J. and Weber, B.R. (1995) The Fate of Darwinism: Evolution after the Modern Synthesis, *Biological Theory*, 6, pp. 89-102
- Dopfer, K. (2005) Evolutionary Economics: A Theoretical Framework, in Dopfer, K. (Ed) *The Evolutionary Foundations of Economics*, Cambridge: Cambridge University press, pp. 3-55.
- Dopfer, K. and Potts, J. (2004) Evolutionary Realism: A New Ontology for Economics, *Journal of Economic Methodology*, 11, pp. 115-212.
- Edelmann, J.B. and Denton, M.J. (2007) The Uniqueness of Biological Self Organisation: Challenging the Darwinian Paradigm, *Biological Philosophy* 11, pp. 579-601.
- Endler, J.A. and McLellan, T. (1988) The Process of Evolution: Towards a New Synthesis, *Annual Review of Ecological Systematics*, 19, pp. 395-421.
- Essletzbichler, J. and Rigby, D. (2007) Exploring Evolutionary Economic Geographies, *Journal of Economic Geography*, 7, pp. 549-572.
- Foster, J. (2010) Evolutionary macroeconomics: A research agenda, *Journal of Evolutionary Economics* 21, 1, pp. 5-28.
- Frank, R.H. (2010) *The Darwin Economy: Liberty, Competition and the Common Good*, Princeton: Princeton University Press.
- Fusco, G. and Minelli, A. (2008) *Evolving Pathways: key Themes in Evolutionary Developmental Biology*, Cambridge: Cambridge University Press.
- Futuyma, D. (1988) Sturm und Drang and the Evolutionary Synthesis, *Evolution* 42, 2, pp. 217-226.
- Garretsen, H. and Martin, R.L. (2010) Rethinking (New) Economic Geography: Taking Geography and History More Seriously, *Spatial Economic Analysis*, 5, pp. 127-160.

- Gersick, C.J.G. (1991) Revolutionary Change Theories: A Multi-level Exploration of the Punctuated Equilibrium Paradigm, *The Academy of Management Review*, 16, pp. 10-36.
<http://www.synapse9.com/ref/GersickCJG1991RevolutionaryChangeTheories.pdf>
- Gould, S.J. and Eldridge, N. (1977) Punctuated Equilibria: The Tempo and Mode of Evolution Reconsidered, *Paleobiology*, 3, pp. 115-151.
- Gould, S.J. and Eldridge, N. (1993) Punctuated Equilibrium Comes of Age, *Nature*, 366, pp. 223-227.
<https://www3.amherst.edu/~jwhagadorn/courses/27paleo/readings/GouldEldredge1993.pdf>
- Grabher G. and Stark, D. (1997) Organising Diversity: Evolutionary Theory, Network Analysis and Postsocialism, *Regional Studies* 31, 5, pp. 533-544.
- Gray, R.D. (2001) Selfish genes or developmental systems?, In *Thinking about Evolution: Historical, Philosophical and Political Perspectives: Festschrift for Richard Lewontin*, Singh, R., Krimbas K., Paul D. and Beatty J., Cambridge University Press: Cambridge.
- Griffiths, P.E. and Gray, R.D. (1994) Developmental Systems and Evolutionary Explanation, *The Journal of Philosophy* 91, 6, pp. 277-304.
- Griffiths, P.E. and Gray, R.D. (2004) The Developmental Systems Perspective: Organism-Environment Systems as Units of Development and Evolution', in M. Pigliucci and K. Preston (eds), *Phenotypic Integration – Studying the Ecology and the Evolution of Complex Phenotypes*, Oxford: Oxford University Press, pp.
- Griffiths, P.E. and Gray, R.D. (2005) Discussion: Three Ways to Misunderstand Developmental Systems Theory, *Biology and Philosophy*, 20, pp. 417-425.
- Gryzmala-Busse, A. (2010) Time will Tell? Temporality and the Analysis of Causal Mechanisms and Processes, *Comparative Politics XX(X)*, ppp. 1-31.
<http://cps.sagepub.com/content/early/2010/12/09/0010414010390653>
- Haldane, A.G. and May, R.M. (2011) Systemic risk in banking ecosystems, *Nature* 469, 351-355.
- Hall, B.K. (1999) *Evolutionary Developmental Biology*, Dordrecht: Kluwer.
- Hall, B.K. (2003) Evo-Devo: evolutionary developmental mechanisms, *International Journal of Developmental Biology* 47, 491-495.
- Harper, D.A. and Lewis, P. (2012) New Perspectives on Emergence in Economics, *Journal of Economic Behaviour and Organization*, (Special Issue on Emergence in Economics), 82, pp. 329-335.
- Harvey, D. (2006) *Spaces of Global Capitalism: Towards a Theory of Uneven Geographical Development*, London: Verso.

- Hensel, P.R. and Diehl, P.F. (1998) Punctuated Equilibrium or Evolution? A Comparative Test of Two Models of Rivalry Development, Mimeo, Department of Political Science, Florida State University
<http://www.paulhensel.org/Research/jcroo.pdf> (Accessed 11 August 2011).
- Hodgson, G. (1993) *Economics and Evolution: Bring Life Back into Economics*, Cambridge: Policy Press.
- Hodgson, G. (2002) Darwinism in Economics: from Analogy to Ontology. *Journal of Evolutionary Economics*, 12(3) pp. 259-281.
- Hodgson, G. and Knudsen, T. (2006) Why we Need a Generalised Darwinism and Why Generalised Darwinism is not Enough, *Journal of Economic Behavior and Organization*, 61(1) pp.1-19.
- Hodgson, G. and Knudsen, T. (2010) *Darwin's Conjecture: The Search for General Principles of Social and Economic Evolution*, Chicago: University of Chicago Press.
- Howlett, M. (2009) Process Sequencing Policy Dynamics: Beyond Homeostasis and Path Dependency, *Journal of Public Policy*, 29, 3, pp. 241-262.
- Jablonka, E. and Lamb, M.J. (2002) The Changing Concept of Epigenetics, *Annals of the New York Academy of Sciences*, 981, pp. 82-96.
- Johnson, B.R. and Lam, S. K. (2010) Self-organisation, Natural Selection and Evolution, *Bioscience*, 60, pp. 872-885.
- Journal of Economic Behaviour and Organisation (2012) Emergence in Economics, *Journal of Economic Behaviour and Organisation Special issue*, 82, 2-3.
- Kitano, H. (2004) Biological Robustness, *Nature Reviews*, 5, pp. 826-837
- Knight, F. (1923) The Ethics of Competition, *Quarterly Journal of Economics*, 37, pp. 579-624.
- Krugman, P. (1996) What Economists Can Learn from Evolutionary Theorists, Paper presented to the European Association for Evolutionary Political economy, <http://web.mit.edu/krugman/www/evolute.html>.
- Laubichler, M. and Maienschein, J. (2007) (Eds) *From Embryology to Evo-Devo: A History of Developmental Evolution*, Cambridge Mass; MIT Press
- Lawson, T. (2011) Ontology and the Study of Social Reality: Emergence, Organization, Community, Social Relations and Artefacts. *Mimeo*, Faculty of Economics, University of Cambridge.
- Lerner, R. M. (2006) Resilience as an Attribute of the Developmental System, *Annals of the New York Academy of Sciences*, 1094, pp. 40-51.
- Levit, G.S., Hossfeld, U. and Witt, U. (2011) Can Darwinism be 'Generalised' and What Use Would This Be? *Journal of Evolutionary Economics*,

doi 10.1007/s00191-011-0235-3.

- Malerba, F. (2010) *Industry Evolution and History-Friendly Models*, Plenary Paper, International Schumpeter Society Conference on Innovation, Organisation, Sustainability and Crisis, Aalborg, June 21-24. <http://www.schumpeter2010.dk/index.php/schumpeter/schumpeter2010/paper/viewFile/491/208>
- Malerba, F., Nelson, R., Orsenigo, L. and Winter, S. (1999) History-Friendly Models of Industrial Evolution: The Computer industry, *Industrial and Corporate Change*, 8, pp. 3-40.
- Marshall, A. (1898) Distribution and Exchange, *Economic Journal*, 8, pp. 37-59.
- Martin, R.L. (1999) The New 'Geographical Turn' in Economics: Some Critical Reflections, *Cambridge Journal of Economics*, 23, pp. 65-91.
- Martin, R.L.(2000) Institutional Approaches to Economic Geography, in Sheppard, E. and Barnes. T (Eds) (2000) *A Companion to Economic Geography*, Oxford: Blackwell, pp. 77-94.
- Martin, R.L. (2010) The Roepke Lecture in Economic Geography - Rethinking Regional Path Dependence: Beyond Lock-in to Evolution, *Economic Geography*, 86(1), pp. 1-27.
- Martin, R.L. (2011) (Re)Placing Path Dependence: A Response to the Debate, *International Journal of Urban and Regional Research*,
- Martin, R.L. (2011b) The 'New Economic Geography': Credible Models of the Economic Landscape? In Leyshon A., Lee, R., McDowell, L. and Sunley, P. (Eds) *The Sage Handbook of Economic Geography*, London, Sage: pp. 53-71.
- Martin, R.L. (2012) Regional Economic Resilience, Hysteresis and Recessionary Shocks, *Journal of Economic Geography*, 12, pp. 1-32.
- Martin, R.L. (2013) Path Dependence and the Spatial Economy: A Key Concept in Retrospect and Prospect, Ch. 34 in Ezcurra, R. and Rodriguez-Pose, A. (Eds) *Handbook of Regional Science*, Berlin: Springer-Verlag, pp.
- Martin, R.L. and Sunley, P.J. (2006) Path Dependence and Regional Economic Evolution, *Journal of Economic Geography*, 6, pp. 395-435.
- Martin, R.L. and Sunley, P.J. (2007) Complexity Thinking and Evolutionary Economic Geography, *Journal of Economic Geography*, 7, pp. 573-602.
- Martin, R.L. and Sunley, P.J. (2011) Conceptualising Cluster Evolution: Beyond the Life Cycle Model? *Regional Studies*,
- Martin, R.L. and Sunley, P.J. (2012) Forms of Emergence and the Evolution of Economic Landscapes, *Journal of Economic Behaviour and Organisation*, (Special Issue on Emergence in Economics), 82, pp. 338-352.

- Martin, R.L. and Sunley, P.J. (2013) On the Notion of Regional Economic Resilience: Conceptualisation and Explanation, submitted to *Journal of Economic Geography*.
- Massey, D. (1992) Politics and Space/Time, *New Left Review*, 196, pp 65-84.
- Masten, A. and Obradovic, J. (2006) Competence and Resilience in Development, *Annals of the New York Academy of Sciences*, 1094, pp. 13-27.
- MacKinnon, D., Cumbers, A. and Pike, A., Birch, K. and McMaster, R. (2009) Evolution in Economic Geography: Institutions, Political Economy, and Adaptation, *Economic Geography*, 85, pp. 129-150.
- Menzel M. and Fornahl, D. (2010) Cluster lifecycles – dimensions and rationales of cluster evolution, *Industrial and Corporate Change* 19, 1, pp. 205-238.
- Metcalf, J.S. (1998) *Evolutionary Economics and Creative Destruction*, London: Routledge.
- Metcalf, J.S., Foster, J. and Ramlogan, R. (2006) Adaptive Economic Growth, *Cambridge Journal of Economics* 30, 1, pp. 7-32.
- Mesoudi, A., Whiten, A. and Laland, K. (2006) Towards a Unified Science of Cultural Evolution, *Behavioural and Brain Sciences* 29, pp. 329-383.
- Müller, G. (2007) Six Memos for Evo-Devo, Chapter 15 in Laubichler, M.D. and Maienschein, J. (Eds) *From Embryology to Evo-Devo*, Cambridge Mass; MIT Press, pp. 499-524.
- Müller, G.B. (2008) Evo-devo as a Discipline, Chapter 1 in A. Minelli and G. Fusco (Eds.) *Evolving Pathways: Key Themes in Evolutionary Developmental Biology*, Cambridge: Cambridge University Press, pp. 3-29.
- Nelson, R.R. (1995) Recent Evolutionary Thinking about Economic Change, *Journal of Economic Literature*, 33, pp. 48-90.
- Nelson, R.R. (2006) *Economic Development from the Perspective of Evolutionary Economic Theory*, Working Papers in Technology Governance and Economic Dynamics No. 2, The Other Canon Foundation, Norway.
- Nelson, R.R. (2007), Universal Darwinism and Evolutionary Social Science, *Biology and Philosophy*, 22(1) pp. 73-94.
- Nelson, R.R. (2011) Economic development as an evolutionary process, *Innovation and Development* 1, 1, 39-49.
- Nelson, R.R. and Winter, S. (1982) *An Evolutionary Theory of Economic Change*, Harvard University Press.
- Norgaard, R.B. and Kallis G., (2011) Coevolutionary Contradictions: Prospects for a Research Programme on Social and Environmental Change, *Geografiska Annaler Series B*, pp. 289- 300.

- Odling-Smee, J. (2010) Niche Inheritance, in Pigliucci, M. and Müller, G.B. (Eds) *Evolution: The Extended Synthesis*, Cambridge, Mass: MIT Press, pp. 175-208.
- Oosterlynck, S. (2011) Path Dependence: A Political Economy Perspective, *International Journal of Urban and Regional Research* 36, 1, pp.158-165.
- Oyama, S. (2000) Causal Democracy and Causal Contributions in Developmental Systems Theory, *Proceedings PSA*, 67, pp. S332-347.
- Oyama, S., Griffiths, P.E., and Gray, R.D. (2001) *Cycles of Contingency: Developmental Systems and Evolution*, Cambridge, Mass.: MIT Press.
- Pigliucci, M. (2007) Do We Need an Extended Evolutionary Synthesis? *Evolution*, 61, pp. 2743-2749.
- Pigliucci, M. (2008) Is Evolvability Evolvable? *Nature Reviews Genetics* 9, Jan, 75-82.
- Pigliucci, M. (2009) An Extended Synthesis for Evolutionary Biology, *Annals of the New York Academy of Sciences*, 1168, pp. 218-228.
- Pigliucci, M. and Müller, G.B. (Eds) (2010) *Evolution: The Extended Synthesis*, Cambridge, Mass: MIT Press.
- Pike, A., Dawley, S. and Tomaney, J. (2010) Resilience, adaptation and adaptability, *Cambridge Journal of Regions, Economy and Society* 3, 1, pp.59-70.
- Raff, R.A. (1996) *The Shape of Life: Genes, Development and the Evolution of Animal Forms*, University of Chicago Press.
- Regional Studies (2011) Cluster Life Cycles, *Regional Studies Special Issue*, 45, 10.
- Reid, R.G. (2007) *Biological Emergences: Evolution by Natural Experiment*, Cambridge Mass: MIT Press.
- Robert, J., Hall, B. and Olson, W. (2001) Bridging the Gap between Developmental Systems Theory and Evolutionary Developmental Biology, *BioEssays* 23, 10, pp. 954-962.
- Sayer, A. (2010) Reductionism in Social Science, Chapter 2 in R.E. Lee (ed) *Questioning Nineteenth Century Assumptions about Knowledge*, New York: SUNY Press, pp. 5-39.
- Setterfield, M. (1998) *Rapid Growth and Relative Decline: Modelling Macroeconomic Dynamics with Hysteresis*, Basingstoke: Macmillan.
- Sewell, W. H. (2005) The Temporalities of Capitalism, *Socio-Economic Review*, 6, pp. 517-537.

- Sheppard, E. (2011) Geographical Political Economy, *Journal of Economic Geography*, 11, pp. 319-332.
- Smith, C.M. and Ruppell, J.C. (2011) What Anthropologists Should Know about the New Extended Synthesis, *Structure and Dynamics*, 5, pp. 1-13.
- Somit, A. and Peterson, S.A. (Eds) (1992) *The Dynamics of Evolution: The Punctuated Equilibrium Debate in the Natural and Social Sciences*, Cornell University Press.
- Storper, M. (1997) *The Regional World, Territorial Development in a Global Economy*, London: Guilford Press.
- Strambach, S. (2008) Path Dependence and Path Plasticity: The Co-Evolution of Institutions and Innovation – The German Customised Business software Industry, *Working Papers on Innovation and Space 02.08*, Department of Geography, University of Marburg.
- Ter Wal, A. and Boschma, R. (2011) Co-evolution of firms, industries and networks in space, *Regional Studies* 45, 7, pp. 919-933.
- Tilly, C. (1984) *Big Structure, Large Processes, Huge Comparisons*, Russell Sage Foundation
- Van de Ven, A. and Poole, M. S. (1995) Explaining Development and Change in Organisations, *Academy of Management Review*, 20, 3, pp. 510-540.
- Visser, G. and Dankbarr, B. (2013) Path Dependence and Path Plasticity: Textile Cities in the Netherlands, *Zeitschrift für Wirtschaftsgeographie*, 57, pp. 83-95.
- Vromen, J. (2007) Generalised Darwinism in Economics - The Devil is in the Details, *Papers on Economics and Evolution No. 0711*, Max Planck Institute of Economics, Jena.
- Vromen, J. (2008) Ontological Issues in Evolutionary Economics: The Debate between Generalised Darwinism and the Continuity Hypothesis, *Papers on Economics and Evolution No. 0805*, Max Planck Institute of Economics, Jena.
- Wagner, A. (2008) Robustness and Evolvability: A Paradox Resolved, *Proceedings of the Royal Society, B: Biological Sciences* 275, pp. 91-100.
- Walsh, D. (2006) Evolutionary essentialism, *British Journal for the Philosophy of Science* 57, pp. 425-448.
- Weber, B.H. (2011) Extending and expanding the Darwinian synthesis: the role of complex systems dynamics, *Studies in the History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 42, pp. 75-81.
- West-Eberhard, M.J. (2005) Developmental Plasticity and the Origin of Species Differences, *PNAS* 102, Suppl. 1, pp. 6543-6549.

- Whitacre, J.M. (2012) Biological Robustness: Paradigms, Mechanism and Systems Principles, *Frontiers in Genetics*, 3, pp. 1-15. doi: 10.3389/fgene.2012.00067
- Wilson, D.S. (2010) Multilevel selection and major transitions, Chapter 4 in in Pigliucci, M. and Müller, G.B. (Eds) *Evolution: The Extended Synthesis*, Cambridge, Mass: MIT Press, pp. 81-94.
- Wimsatt, W. (2006) Generative entrenchment and an evolutionary developmental biology for culture, *Behavioural and Brain Sciences* 29, 4, pp. 364-366.
- Witt, U. (2003) *The Evolving Economy: Essays on the Evolutionary Approach to Economics*, Cheltenham: Edward Elgar.
- Witt, U. (2004) On the proper interpretation of 'evolution' in economics and its implications for production theory, *Journal of Economic Methodology* 11, 2, 125-146.