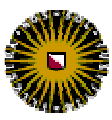
Papers in Evolutionary Economic Geography

07.02

Exploring Evolutionary Economic Geographies

Jürgen Essletzbichler and David L. Rigby



Utrecht University
Urban & Regional research centre Utrecht

Exploring Evolutionary Economic Geographies

Jürgen Essletzbichler* and David L. Rigby**

*Department of Geography
University College London
26 Bedford Way
London, WC1H 0AP
UK
e-mail: j.essletzbichler@ucl.ac.uk

**Department of Geography
Bunche Hall 1255
University of California Los Angeles
Los Angeles, CA 90095-1524
USA
e-mail: rigby@geog.ucla.edu

ABSTRACT:

Evolutionary approaches in economics have gathered increasing support over the last 25 years. Despite an impressive body of literature, economists are still far from formulating a coherent research paradigm. The multitude of approaches in evolutionary economics poses problems for the development of an evolutionary economic geography. For the most part, evolutionary economic geography imports selective concepts from evolutionary biology and economics and applies those concepts to specific problems within economic geography. We discuss a number of problems with this approach and suggest that a more powerful and appealing alternative requires the development of theoretically consistent models of evolutionary processes. This paper outlines the contours of an evolutionary model of economic dynamics where economic agents are located in different geographical spaces. We seek to show how competition between those agents, based on the core evolutionary principles of variety, selection and retention, may produce distinct economic regions sharing properties that differentiate them from competitors elsewhere. These arguments are extended to illustrate how the emergent properties of economic agents and places co-evolve and lead to different trajectories of economic development over space.

KEYWORDS: evolutionary economics, economic geography, Generalized Darwinism, biological metaphors, self-organization.

INTRODUCTION

Over the past decade, biological and evolutionary metaphors and concepts such as path-dependence, variety and selection have become increasingly popular with economic geographers (Amin 1999; Barnes 1997; Boschma and Frenken 2006; Boschma and Lambooy 1999; Boschma and Van der Knaap 1997; Essletzbichler 1999; Essletzbichler and Rigby 2005a, b; Grabher 1993; Grabher and Stark 1997; Hudson 2001; Martin 2000; Martin and Sunley 2006; Rigby and Essletzbichler 1997, 2006; Storper 1997; Webber et al. 1992). Still, it remains unclear what an evolutionary approach to economic geography might entail, and whether, and in what ways, an evolutionary perspective might differ from other theoretical frameworks. In this paper we explore the boundaries, potentials and shortcomings of a theoretically consistent, evolutionary approach within economic geography.

Modern evolutionary economic theory emerged in the 1970s largely in opposition to the core assumptions of mainstream, neoclassical economics (Nelson and Winter 1974). Evolutionary economics targeted issues that neoclassical theory then seemed least capable of explaining in depth, namely economic growth (Nelson and Winter 1982; Nelson 1995; Verspagen 2001), technological change (Arthur 1983, 1989; David 1985; Dosi 1982; Dosi et al. 1988; Pavitt 2005), industrial evolution (Abernathy and Utterback 1978; Klepper and Graddy 1990; Klepper 2001), the nature of competition and the role of institutions and routines in guiding individual behavior (Hodgson 1988, Nelson 2001, Veblen 1898). As the approach matured, debates over appropriate foundations and the style of evolutionary economic theory emerged (Hodgson 2002; Knudsen 2002; Witt 2004). The first section of this paper briefly reviews these debates and leads to an outline of the fundamental arguments of an evolutionary approach to economic change.

The second section of the paper highlights existing work in economic geography that claims links to evolutionary theory. For the most part, this work adopts concepts from evolutionary biology and economics in a rather uncritical and piecemeal fashion. We discuss some problems with this approach and suggest a more powerful and appealing alternative rests on understanding how core evolutionary processes operate within space. This task begins in a third section that outlines the contours of an evolutionary model of economic dynamics where economic agents are located in different geographical spaces. We seek to show how competition between those agents, based on the core evolutionary principles of variety, selection and retention, may produce distinct economic regions sharing properties that differentiate them from elsewhere. These arguments are extended to illustrate how the emergent properties of economic agents and places co-evolve and lead to different trajectories of economic development over space.

EVOLUTIONARY ECONOMICS: BASIC PRINCIPLES AND CONCEPTS

The history of evolutionary strains within economics is long, though it is by no means continuous, unidirectional or uncontested, either from within or without. Early linkages between economics and biology in the writings and acknowledgements of Darwin, Spencer and Malthus are well-known (Young 1969; Hodgson 1993). While the roots of neoclassical economic theory were laid down in the 1850s and 1860s

(Jevons 1871; Walras 1926), increasingly to be nurtured by the adoption of methods heavily reliant on physics, Veblen (1898) was already asking 'Why is Economics not an Evolutionary Science?', expressing disquiet at the inability of a static neoclassical theory to explain economic change. He sought that explanation in Darwinian terms through a cumulative process by which competing routines, or habits of thought, become settled and selected, leading to environmental change and further institutional adaptation. Marshall (1920) too was dissatisfied with the mechanics of neoclassical economics, and called for the discipline to return to the 'mecca' or fertile ground of biology, yet the core of his Principles steers an awkward passage away from that ground, never to return. In this early period of evolutionary economic development, the role of Joseph Schumpeter (1939, 1942) must not be overlooked. Though Schumpeter rejected appeals to biological analogies (Foster 2000; Witt 2002), there is little question that his vision of creative destruction was evolutionary in form and fundamentally inconsistent with the notion of a stable competitive equilibrium (Hodgson 1993; Andersen 1994).

The more recent engagement with evolutionary economics can be traced to the pioneering efforts of Nelson and Winter (1982). In part, this work originated in attempts to engage the selection arguments of Alchian (1950) and to rebuff the 'as if' claims of Friedman (1953), the search to ground marginalist claims of profit maximization within an evolutionary selection framework (Vromen 1995). However, Nelson and Winter's work became much more, offering a model of evolutionary economic dynamics, and standing as prelude to the most sustained period of development that evolutionary economics has yet seen.

While most evolutionary economists are united by rejection of the assumptions of full information and perfect rationality that underpin mainstream neoclassical economics, they remain far from formulating a common research paradigm, agreement on basic principles, or even on the best way to carry the framework forward (Hanappi 1995). Hodgson (1993, 2002), Knudsen (2002, 2004) and Witt (2004) discuss the different ways that evolutionary arguments have been extended into the domain of economic activity. The most well-known of these are briefly introduced next.

A first strategy involves application of the neo-Darwinian theory of natural selection directly to human behavior, and is closely linked to socio-biology (Wilson 1975; Becker 1976). Thus, because humans are products of natural selection, and because economic actions result from human activity, economic behavior should be explicable on the basis of how it is correlated with the genetic fitness of individuals (Witt 2004: 127). Because this approach only applies to genetically determined forms of behavior, because it ignores human intentionality and demands complete separation of genetic information, or social equivalents, from the selection environment it has tended to gather little recent support (Hodgson 2004; Vromen 2004).

A second strategy is to make use of Darwinian principles in a purely heuristic or metaphorical fashion. In this case, different concepts are imported to derive "metaphoric inspiration" or to construct analogies between evolutionary biology and evolutionary economics (see Hodgson 1993). This approach is widely applied in economics and economic geography, though perhaps a little too uncritically. While there is little question of the usefulness of sharing ideas across the natural and social

sciences, there are concerns with the inconsistency of eclecticism (Fincher 1983), and with the too rigid interpretation of analogies across disciplinary boundaries. Prominent examples include attempts to use the process of natural selection to sustain arguments about rational economic behavior, profit maximization (Friedman 1953; Hirschleifer 1977) and competition, or to view competition as a process that necessarily leads to efficiency (Hodgson 1993; Sheppard 2000; Sober 1984). Witt (2004) also believes certain concepts that are clearly defined in evolutionary biology are impossible to define in social systems and thus a close or true analogy is unlikely.

We argue that the third main strategy, based on Generalized Darwinism, is the most appealing path for the development of evolutionary economics and its extension into economic geography. Generalized Darwinism asserts that the core principles of evolution provide a general theoretical framework for understanding evolutionary change in all domains (from physical to social systems), but that the meaning of those principles and the way that they operate is specific to each domain (Hodgson 2002; Knudsen 2004; Hodgson and Knudsen 2006). Thus, to understand economic evolution from the approach of Generalized Darwinism demands understanding what the key concepts of variation, selection and continuity might represent in the economy, how those concepts are put into motion, or embedded within a dynamic system of economic competition, and how they are influenced by other mechanisms specific to that system. As Vromen (2004) notes, the aim of this approach is not to see whether economic evolution can fit the general schema of Generalized Darwinism, but rather, to see whether analysis of economic dynamics using these principles provides novel insight into the movement of the economy over time.

The fundamental aim of evolutionary economics is thus to understand the dynamic processes that jointly influence the behavior of firms and the market environment in which they operate (Nelson and Winter 1982). These processes can be considered evolutionary in the sense that the capitalist economy consists of competing agents that differ in at least some characteristics (heterogeneity) that influence individual prospects for economic growth (selection), and that change more or less slowly over time (heredity), both shaping and being shaped by the environment within which future competition unfolds (Hodgson 1993, 2002; Metcalfe 1988; Saviotti and Metcalfe 1991).

Within the capitalist mode of production, firms differ from one another across a series of dimensions - product type, technology, organizational form, location and the behavioral routines adopted to regulate processes of investment, labor management, technological search, etc. This heterogeneity is an inevitable byproduct of competition and innovation within an economy where production is carried out by private firms all motivated by profit but limited by information asymmetries and uneven capabilities (Alchian 1950). Uncertain of the future, firms control whatever they can as best they can, seeking competitive advantage by increasing the efficiency of production. For most, however, efficiency is unknown until they enter the market. In this competitive environment firms are compelled to innovate, to search for new products and develop new markets, to experiment with new sources of inputs, new processes of production

and organizational routines, sure only in the knowledge that others are doing the same (Schumpeter 1942)[1].

The competitive process of market selection regulates the profitability of individual firms, their prospects for growth, and their ability to generate new routines. Selection thereby alters the environment within which future decisions are made: it pushes some firms out of the market, encourages others to enter, and reshuffles the relative efficiency of competing agents. It is important to note that the process of selection does not identify and reward more efficient firms. Rather, sales are spread unevenly across competitors in a market. On average, those firms that produce a commodity more efficiently are better able to translate revenues into profits and thus, given a certain propensity to invest, increase their relative size at the expense of firms that are relatively inefficient. Some firms deliberately attempt to alter the selection environment in which they find themselves, perhaps by differentiating the commodity they offer for sale and thus competing in a particular niche market. Regardless, they are still hostage to the same uncertainty that pervades all unregulated markets.

For selection to operate a certain level of stability, or inertia, in firm characteristics is required. In a world of infinite malleability and instantaneous adaptability variety disappears and there is nothing to select. Sunk capital investments, contractual relationships, organizational strategies and the accumulated knowledge base of the firm generate the necessary institutional inertia that allows selection to operate. Nelson and Winter (1982) argue that firms develop routines to cope with decision-making and that these change only slowly in reaction to shifts in the environment. It is these behavioral routines that play the role of heredity in the evolutionary economic model, preserving some continuity over time in firm characteristics (Metcalfe 1998). While they tend to be relatively stable in the short run, the behavioral routines of firms do change, the result of profit-induced search, learning, imitation, and chance, by adaptation to the changing economic environment and as part of their efforts to strategically manipulate that environment. As long as economic agents are boundedly rational and as long as some form of inertia exists that enables differences in behavior to persist, forces of selection will operate and economic evolution will run its course (Simon 1957; Hodgson 2001; Hodgson and Knudsen 2004).

These broad principles of evolutionary change have found increasing application within economics and related fields over the past twenty years or so. Following Nelson and Winter (1974, 1982), a prominent focus of this literature has been industrial dynamics (Baldwin 1995; Klepper 1996, 2001). In support of these arguments, Nelson (1995), Cohen and Levinthal (1989), Rigby and Essletzbichler (2000, 2006) explore the existence and persistence of variety in firm technologies and organizational routines. Saviotti (1996), Cantner and Hanusch (2001) and

[1] Our explanation of the introduction of variety is different from that of Foster (2000) and Witt (2004) who explain the emergence of variety through "the entrepreneurial desire to discover new and profitable organizational combinations" (Foster 2000: 319). Both refer to a natural predisposition of humans to engage in novelty generating activities. We do not agree with a view that reduces the explanation of the generation of variety to preferences and desires of individuals because it comes too close to Dawkin's (1976) selfish gene analogy. We believe that ideas, desires, preferences are the result of individual thought processes that are in part influenced (but not determined) by the environment in which individuals operate. In contrast to biology, the creation of variety and selection are thus intrinsically related in economics.

Essletzbichler and Rigby (2005b) propose different interpretations of selection that act upon this heterogeneity. In more specific accounts, Silverberg (1988) and Verspagen (2001) explore shifts in the distribution of industry productivity and unit cost. Search routines and patterns of innovation that lead to the generation of heterogeneity are explored by David (1975), Metcalfe and Gibbons (1986), Dosi (1988, 1997) and Webber et al. (1992). As new forms of firm-level data have been developed, so analysis of industry and technological evolution has increasingly taken advantage of these sources (Audretsch 1995; Baldwin 1995; Bartelsman and Doms 2000; Rigby and Essletzbichler 2006). At the same time, newer models of evolutionary dynamics have emerged, building on more sophisticated understandings of population dynamics (Iwai 1984a,b; Metcalfe 1998; Andersen 2004).

Evolutionary arguments appear to hold much promise for the analysis of economic dynamics. Nonetheless, many potential stumbling blocks remain:

1. For some, evolution does not require a theory of innovation. For evolution to proceed it is sufficient (and necessary) merely that variety exists (Metcalfe 1998). However, innovation, or the creation of heterogeneity, is a necessary process of long-run evolution in systems that are not degenerate. Within the capitalist economic system, it is impossible to comprehend the process of competition without innovation and the shadow of uncertainty that it casts. Generalized Darwinism handles the creation of variety through the process of generative selection (Hodgson and Knudsen 2006), but changes occurring through self-transformation or development will have to be included as well (Metcalfe and Foster 2001).
2. The principle of self-organization, i.e. the emergence of patterns through interaction between entities that cannot be reduced to properties of those entities, is potentially important to explain evolutionary processes not only in social and cultural but also in biological systems, in particular the emergence of novelty (Kaufman 1993; Depew and Weber 1995, 1996; Foster 2000, 2001)[2]. However, it is unclear whether the principle of self-organization can be accommodated within the framework of Generalized Darwinism, although a synthesis of the two frameworks appears possible and even necessary (Depew and Weber 1995, 1996; Foster and Metcalfe 2001; Hodgson and Knudsen 2006; Kaufmann 1993, 2000; Metcalfe 2005). Self-organization can explain how order may emerge from interacting agents "but itself it explains neither (a) the characteristics of the agents that interact to create the emergent order, (b) how the emergent order reacts to competing social orders, nor (c) more generally how an emergent order adapts and survives in the broader social and natural environment" (Hodgson and Knudsen 2006: 9). The principles of self-organization and selection appear thus complementary rather than contradictory. While self-organization deals with the self-transformation of entities, selection examines the interaction of those entities with their environment and in turn, explains why certain entities survive and thrive while others decline and perish in specific environmental contexts.

[2] Foster (2000) discards evolutionary theory for its apparent inability to account for the endogenous production of novelty. According to Foster (2000), novelty can only be triggered by exogenous environmental shocks in an evolutionary framework. Vromen (2001) contests this claim and demonstrates that evolutionary theory does not preclude the endogenous creation of novelty.

3. Within the evolutionary framework more squarely, it is still unclear whether firms are the most appropriate unit of selection within the economy[3]. Further, we do not really know the characteristics of those units that are most critical in terms of selection, nor how the pressure of selection shifts as firms and industries mature.
4. Additional work is also required to understand the interaction between individual units in populations of interest and the "environment" that they shape and within which they evolve. For example, what evolutionary processes give rise to path dependence, why do some emergent properties of systems get "locked-in" for shorter or longer periods, through precisely what mechanisms is such stability maintained and how is it overturned?

EXISTING WORK IN EVOLUTIONARY ECONOMIC GEOGRAPHY

Over the last decade or so, economic geographers have frequently employed evolutionary concepts and metaphors such as routines, path-dependence, lock-in, and co-evolution (Barnes 1997). For the most part, these concepts are deployed in an isolated, descriptive manner or they are grafted to poorly specified theoretical frameworks. While we are encouraged to see the growing use of evolutionary arguments, and consider them to hold much promise for understanding the processes influencing regional economic growth and change, we believe that they would gain considerable analytic power if developed explicitly as an alternative approach within economic geography. To date, there is no general evolutionary approach to economic geography embodying the abstract principles of Generalized Darwinism, self-organisation or path-dependence, though more limited evolutionary forays do exist (Boschma and Lambooy 1999; Boschma and Van der Knaap 1997; Boschma and Frenken 2006; Frenken and Boschma this issue; Bottazzi et al. this issue; Maskell and Malmberg this issue; Essletzbichler 1999; Rigby and Essletzbichler 1997, 2006). In this section we do not attempt to review all work in economic geography that rests on evolutionary foundations. Rather, we aim to summarize some of the main themes readily identified in the literature.

The localized nature of innovation and technological change

The introduction of product and process variety in the form of technological change is one of the dominant research areas in evolutionary economics. At the micro-level the distinctive features of an evolutionary approach to technological change include the insistence on bounded rationality (Simon 1957) and the importance of firm routines that guide processes of innovation and adaptation. Bounded rationality implies that actors will search locally: they will explore those areas of the search space with which they are most familiar rather than scanning all possibilities (Antonelli 1997; Dosi 1997). The geographic dimension of local search in technology space has been explored through the concept of (geographically) localized search and learning (Maskell and Malmberg 1999; and this issue). At the meso- and macro-levels an evolutionary approach recognizes that the search for novelty is a social process including complex feedback mechanisms between various actors as well as the

[3] Multi-level selection theory and group selection are possible ways out of this dilemma and potentially important for the development of an evolutionary economic geography (Sober and Wilson 1998; Vromen 2001).

importance of social institutions that steer the path of technology creation in specific directions while obscuring and excluding alternatives.

Economic geographers, as well as heterodox economists, have examined the influence of geography on search processes (Audretsch and Feldman 1994, Jaffe et al. 1993). The work on national and regional innovation systems (Brazyk et al. 1998; Lundvall 1992; Johnson and Gregerson 1997), learning regions (Maskell and Malmberg 1999) and competence regions (Lawson 1999) identifies the production of novelty as the key element of regional economic success, postulates that the exchange of (tacit) knowledge (Teece 1986) is (geographically) localized and that institutions and (cooperative) relationships between regional actors are of critical importance for successful innovation (Cooke and Morgan 1998). At the regional level, institutions, broadly defined as “settled habits of thought” (Veblen 1899), play a similar role to routines at the firm-level. They channel the search for innovations into those realms of technology space that agents are most familiar with. This is a result of the co-evolution of institutions, firms and technologies (Nelson 2001). Thus, geographically localized search results in the path-dependent evolution of technology, revealed as spatial variations in plant technology and region-specific trajectories of technological change (Essletzbichler and Rigby 1997, 2005), and/or patterns of industrial specialization (Maskell and Malmberg, this issue).

Research on the localized nature of innovation and technological change highlights the evolutionary principles of variety creation and retention/transmission of information but usually neglects other aspects of an evolutionary approach. Thus, it is often assumed that once new technologies emerge, they will become dominant, along with the regions in which they were created. The story of technological ascent and, in particular, decline is typically neglected. Consequently, we know little about why some new technologies become standard, while others disappear? Similarly, we don't understand why certain regions are able to continually adapt to a changing economic environment, despite firm-level routines and institutional inertia, while others seem to become locked in an increasingly uncompetitive past (Grabher 1993; Martin and Sunley 2006)? New technologies may be necessary but they may not be sufficient to guarantee the survival of firms, industries and regions in a continually evolving economic environment.

Firm, industry, cluster, regional life cycles

Work on the spatial evolution of firms and industries is influenced by product and industry life-cycle studies pioneered by Griliches (1957), Utterback and Abernathy (1975), Abernathy and Utterback (1978), Klepper and Graddy (1982), Klepper (1996) and Utterback and Suarez (1993). The key insight from these studies is that the different processes of evolutionary change vary in intensity over industry life-cycles. High levels of technological and market uncertainty accompany competing designs at early stages, along with high levels of entry and exit. Winners are difficult to predict, arising through historical accident, through uneven competitive struggle, market manipulation, and in rare cases, perhaps, superior characteristics. Once "dominant designs" (Sahal 1982; Dosi 1982) emerge the nature of innovation shifts from product to process and entry rates fall while exit rates remain high through intense selective pressure. The result is thought to be a rapid narrowing of heterogeneity and gradually

increasing rates of market concentration. Although the industry life-cycle model is not universally applicable (see Storper 1987), it does seem to offer a reasonable account of the pattern of evolution in several industries (Mowery and Nelson 1999; and see Klepper 2001; Klepper and Simmons 2000a,b).

There are at least three different approaches that contribute to an understanding of the spatial evolution of an industry. The first approach explains the spatial evolution of an industry through the locational strategies of entrants (Arthur 1994). The second approach explains industrial evolution through spin-off dynamics (Boschma and Wenting 2007; Klepper 2001, Klepper and Simmons 2000). Both approaches are well known and are not discussed in any detail. It is sufficient here to point out that Arthur's model highlights the evolutionary principles of *path-dependence,* while the spin-off models emphasize routines and the principle of *retention/transmission* of information.

A third approach may be called the "windows of locational opportunity" (WLO) approach (Boschma and Van der Knaap 1997) and provides a framework to explain the evolution and lock-in of industries in space. The model suggests that at any moment in time technical problems, labor conflicts, or market opportunities may serve as triggers of major innovations in a large number of regions. While the number of triggers is infinite and randomly distributed across space, the WLA approach looks at why new industries based on those innovations get locked into particular regions. The main argument is that fundamentally novel innovations require different sets of skills, process technology, supplier and customer linkages and institutions, eroding the competitive advantages of existing regional production systems. Because no single region has yet developed the locational characteristics and an appropriate institutional environment adapted to the needs of the new industry, agglomerations containing diverse pools of skilled labor, industries, firms, and institutions are at an advantage (Boschma and Van der Knaap 1997; Boschma and Lambooy 1999). At this stage agglomeration economies are beneficial to attract emerging industries. Once dominant designs emerge and the requirements for competitive success can be defined, industries start to develop their own environment through the establishment of supplier and customer networks, research institutions, industry organizations, skills training programs and so on. Storper and Walker (1989) call this process "industrial territorialization" (see also Cronon 1991 on the evolution of Chicago). At this point the spatial system enters an important juncture. Regions that have been able to attract firms in the new industry and that are able to develop industry-specific regional assets will surge ahead. At some point their advantage becomes so great that new entrants have no option but to enter in the dominant region(s), while firms elsewhere will be driven out of business, leading to geographic concentration.

The role of institutions and socio-economic culture

Institutional approaches within economic geography do not constitute a unified paradigm but a call to broaden the sub-field to include institutional, cultural and social factors and processes in order to understand the economic evolution of regions. For broad reviews of the 'institutional turn' in economic geography see Amin (1999), Martin (2000) and Peck (2006). Institutions may be interpreted "as containers of socioeconomic organisation, and […] as processes of institutionalization of socio-economic practices" (Amin 2001: 1237). In this section we talk mostly about the former since this is the interpretation most commonly

applied by evolutionary economists and economic geographers. Institutions include formal structures such as legal rules, property laws, state policies and technological standards, as well as informal habits, codes of conduct, organizational cultures and conventions that provide stability and inertia and guide individual action.

Although most work on regional economies examines the effect of formal concrete organizations such as research institutions and incubators, differences in the provision of finance and skills training programs or the influence of government policies on regional economic performance (Lundvall 1992; Brazyk et al. 1998), "relational assets" based on the social properties of (localized) networks including tacit knowledge, embedded routines, habits and norms, local conventions of communication and interaction, reciprocity and trust are increasingly employed by economic geographers to explain differences in performance (Amin 1999; Amin and Thrift 1995; Gertler 2005; Storper 1997). Geographic proximity is required to develop these relational assets to form the competitive advantage of learning regions and regional innovation systems (Cooke and Morgan 1998; Edquist 1997).

In evolutionary economics, institutions are understood as relatively stable entities that change only slowly over time and thus perform a similar function to routines at the firm level. They are crystallized past social practices that inform individual actions such as investment decisions, the search for novelty, or job training. Institutions become carriers of information passed on over time through the influence exerted on individual decision makers. Because different institutions operate over various spatial scales and tend to be geographically and temporally embedded, the influence of institutions on economic actors such as firms and workers will exert region-specific pressures. Institutional differences may thus also be interpreted as differences in the regional selection environment influencing the action of local agents in similar ways. Berman and Bui (2001) offer an excellent study of the visible effect of institutional change on plant performance. They study the effect of lower emission targets for Californian oil refineries. Lower emission targets not only resulted in lower emissions but also in improved productivity of Californian plants since they were forced to introduce newer, cleaner technologies that happened to be also more efficient than older technologies employed by their Texan competitors. Differences in the regional institutional environment (in this case environmental regulation) changes individual (plant) performances in the region at the same rate. Evolutionary theorists call this process group selection (Gowdy 1994; Vrba and Gould 1986).

Because economic geographers tend to study successful innovation systems, learning regions and competence regions, they tend to over-emphasize the positive role of strong, local interaction without considering the pitfalls. Many once-prosperous learning regions such as the German Ruhr or the English Northeast, characterized by deep ties between regional actors and an institutional environment well-adapted to past economic circumstances, paid the price for those ties once economic conditions changed (Grabher 1993; Grabher and Stark 1997; Granovetter 1973; Hudson 1999). Because institutions are often slow to form and perhaps even slower to adapt, they pose problems for long-run regional sustainability: thick and sticky are not always a virtue.

The inclusion of institutions has certainly benefited our understanding of regional economic evolution. However, institutional analysis is not restricted to evolutionary economics and is thus insufficient to demarcate an evolutionary approach. While orthodox theory interprets the emergence of institutions as outcomes of decisions by rational agents (institutions are adopted if they increase efficiency), evolutionary theory interprets them as self-organized systems emerging from interaction among bounded rationally agents. The outcome of the institutional environment is generally unpredictable and often the unintended consequence of individual decision-making. At the moment, institutional analysis is only loosely related to theories of economic evolution. The question is whether work on institutions could be embedded more carefully in an evolutionary economic geography.

Jessop (2001) provides some interesting suggestions. He urges analysts to provide sharper definitions of institutions and careful analysis of reproduction of institutions as they are performed through routine actions. "One might then look behind the naturalization of

institutions to examine institutional emergence as a complex evolutionary phenomenon that depends on specific mechanisms of variation, selection and retention in specific spatiotemporal contexts" (Jessop 2001: 1221). Analysis of the emergence of institutions could be embedded more carefully in an explanatory scheme of Generalized Darwinism. Once that is accomplished, it would be possible to study the relationship between institutions and the systemic environment. Institutions could then be regarded as meso-level structures between individual decision-making and the macro-environment. How institutions co-evolve with micro- and macro-levels in a specific spatio-temporal context opens up a complex set of questions related to "issues of path-dependence, path shaping and metagovernance […]" (Jessop 2001: 1221).

A note on path-dependence and lock-in

Perhaps the most widely employed evolutionary concepts in economic geography are those of *path-dependence* and *lock-in*. While these concepts were developed originally to demonstrate how cumulative change and network externalities can lead to the adoption and lock-in of inferior products and technologies (Arthur 1983, 1989, 1994; David 1975, 1985), path-dependence and lock-in can have found analytical traction in a regional context (Boschma 2004; Gertler 2005; Grabher 1993; Grabher and Stark 1997; Hassink 2005; Storper 1997). For an excellent discussion of this work see Martin and Sunley (2006). Although the concept of path-dependence has enriched our understanding of regional evolution, it is unclear that adoption of this concept is consistent only with evolutionary claims. Path-dependence is itself an outcome of various causal mechanisms[4] and on its own lacks explanatory power. Models of location theorists (Weber 1929; Hoover 1948), Marxists (Harvey 1982; Massey 1984), new geographical economists (Krugman 1991; Fujita et al. 1999), Neo-Ricardians (Scott 1988, 2006), and those of economic geographers working within the institutional and 'cultural turn' perspectives (Amin 1999; Brazyk et al. 1998; Brusco 1982; Cooke and Morgan 1998; Grabher 1993; Grabher and Stark 1997; Saxenian 1994) give rise to patterns of regional development that are generally viewed as path-dependent, even though they highlight different underlying causal processes. Path-dependence and lock-in are useful metaphors to explain regional change, but they are insufficient to demarcate an evolutionary economic geography from other research traditions and cannot serve as the conceptual vehicle of a broader evolutionary economic geography.

In conclusion, we do not question the usefulness of applying evolutionary metaphors to understand economic geography. However, we do question claims that application of these metaphors renders work evolutionary. We have tried to stress in the brief review above, that the metaphors employed may be consistent with a variety of analytical frameworks, of which evolutionary theory is but one. More careful development of the principles of Generalized Darwinism within economic geography offers much more.

DEVELOPING AN EVOLUTIONARY ECONOMIC GEOGRAPHY

[4] Martin and Sunley (2006, Table 4) identify the presence of natural resources, sunk costs of local assets and infrastructure, local external economies of industrial specialization, regional technological 'lock-in', economies of agglomeration, region-specific institutions, social forms and cultural traditions and interregional linkages and interdependencies as possible causes of path-dependence and lock-in and suggest that path-dependence may be the outcome of broader evolutionary processes such as the creation and destruction of variety.

In this section of the paper we outline the conceptual foundations of an evolutionary approach to regional uneven development. Our aim is to reveal the utility of the core principles of Generalized Darwinism within the domain of economic geography. We do not insist that evolutionary arguments are necessarily the most useful for the study of regional economic dynamics, merely that they provide a different perspective that offers novel insights. We do believe that an evolutionary framework has considerably more to offer than a few descriptive metaphors. In the limited space available, we cannot hope to provide a fully-fledged evolutionary model of economic dynamics in space. Rather, we seek to provide a general introduction to the role of variety, selection and continuity in shaping economic dynamics, the way that these processes are influenced by space, and in turn, influence the evolution of regional economies.

The basic concepts of an evolutionary understanding of economic change were outlined above. These form the essential building blocks around which evolutionary accounts of regional economic dynamics have to be structured. Those accounts rest upon a population of competing entities, at least some of which have unique characteristics that lead to a differential allocation of resources that constrain behavior. The movement of the system as a whole reflects changes in the relative weights of the different entities, the birth of new competitors and elimination of existing ones, and processes of transformation that alter the characteristics of individual units. As we move to consider the evolution of the space economy, we must also examine the ways that selection environments (spaces of competition) are produced and transformed by the actions of individual economic agents, broader coalitions and institutions, and how the characteristics of those spaces influence patterns of economic change.

Evolutionary approaches to economic dynamics have a number of potential points of departure. The units of selection that ground an evolutionary account could be firms, workers, specific technologies or routines, or even competing modes of regulation found in particular places. We have tended to choose the business establishment (plant) as our basic unit of analysis and so privilege the economic dynamics that originate in plant-level competition. A consideration of evolutionary dynamics over space raises the question of whether regions themselves might be considered as units of selection. We suggest that they should not, as this would represent another form of spatial fetishism. However, we do accept the hierarchical view of evolution endorsed by a growing number of researchers (Gould and Vrba 1986; Gowdy 1992; Hodgson 2001; Levins and Lewontin 1985; Lewontin 1970). Evolutionary economic geographies must focus on evolution *in* a region as well as the evolution *of* regions. We will develop these concepts through the arguments below.

Evolution in the region

We start our analysis of regional economic change by considering the evolution of a population of plants that compete with one another within a common selection environment, perhaps understood as a single region. The general delineation of this region might be the result of technology, fixed over the short-run by the costs of transport, from political fiat, or from development of an institutional fabric given local coherence by shared history. Economic growth and change in this economy may be understood as a simple aggregate of changes in the underlying distribution of plants.

Formal analysis of population dynamics results from the work of Fisher (1930) and his fundamental theorem of natural selection that states the rate of increase of aggregate fitness in a population is dependent on the variance of fitness across the units that comprise that population. In our context, we might restate Fisher's theorem as aggregate regional economic performance depends on the variance in levels of performance across the plants within the region. It is important to note that Fisher's argument captures a simple distance-from-mean replicator dynamics, whereby more (less) efficient plants enjoy above (below) average growth rates. Plant entry and exit can be incorporated within this model of selection.

Fisher's theorem is important for understanding population thinking and the process of selection. It leads to a consideration of the properties that are selected for within a population of interest and it focuses attention on the strength of the process of selection. However, Fisher's theorem alone offers only a partial account of evolutionary dynamics because it does not explain the generation of novelty. Within the economy, at least, there is surely little question that competitive advantage and growth hinge on technological change, on processes of learning, imitation and innovation: the deliberate search by economic agents to improve their performance (Price 1970; Metcalfe 1998; Andersen 2004). Price extends Fisher's arguments to show how the effects of selection and technological change can be integrated to account for shifts in aggregate performance across a population of competing economic units. Technological change here is used broadly to represent any alteration in production technology, organizational form, behavioral routines or related characteristics of plants that impact efficiency.

Figure 1 illustrates these arguments, showing how changes in aggregate production technology have been influenced by plant entry and exit, processes of differential plant growth (selection) and by technological change within incumbent plants for a number of US (4-digit SIC) manufacturing industries between 1963 and 1992. Here we assume, for the sake of convenience, the US economy comprises our selection environment. For each industry, the horizontal bars in Figure 1 measure the relative contribution of the different evolutionary processes that cause labor and capital input coefficients to vary over time.

Figure 1 about here

The theoretical frameworks developed by Fisher and Price help us understand the broad movement of the economy from a population perspective (Mayr 1984). Building on these foundations, more specific evolutionary arguments outline how processes of competition give rise to the particular configurations of technologies and institutions that we observe. In terms of technology, considerable attention has been given to the way in which heterogeneity shapes both the direction and pace of change. From the work of Hicks (1933), Habbakuk (1962), David (1975), Metcalfe and Gibbons (1986) and Webber et al. (1992), we know that the form or shape of technological variety influences the direction of imitation within an economy, and how innovation is guided by relative prices. Those prices are part of the selection environment within which plants compete, they are generated by the choices of individual plants, through market processes of supply and demand, as well as through political contest, particularly in the case of wages.

The extent of variety within a selection environment is also thought to control the pace of aggregate change, after Fisher (1930). Much less clear, however, are the precise linkages between aggregate change, the strength of selection and the generation and destruction of heterogeneity. In particular, how does the variance in plant characteristics influence the pressure of selection; to what extent can inefficiency (perhaps thought of as a measure of variety) be subsidized as a hedge against the lock-in of characteristics that may prove unprofitable in the long-run; how does lock-in occur and how is it overturned? Here there is great need for careful historical accounts of industrial and regional development, of the generation of new products and processes of production, of competition between firms and technologies and resulting aggregate dynamics. Ideally, that history would trace the strategies and fortunes of individual business units, linking economic data for establishments and industries in particular places with firm ethnographies and other narratives to understand the development of place-specific institutions and the broader evolution of the selection environment.

It is increasingly clear that plants and industries do not evolve in a vacuum but co-evolve with other economic agents and alongside the broader institutional settings that sometimes develop within the regions in which they are embedded (Nelson 1995; Freeman 1995). Setterfield (1993) discusses how the rules and behavioral norms that comprise institutions emerge from the interaction of economic agents and the structures that regulate their activity, in a process of hysteresis. David (1992) offers a similar claim, with positive feedbacks generating that hysteresis. These arguments are consistent with the view that institutions are endogenously generated among populations of actors that engage in sustained social interaction. Indeed, Setterfield (1993) envisions a process of institutional creation and selection that is explicitly evolutionary in nature. As this interaction is bounded by the region that comprises the selection environment, it is likely that a set of broad regional social structures will emerge to co-ordinate economic activities. These institutional arrangements exist outside the boundaries of individual economic agents to deal with common problems in a manner consistent with the claims of Granovetter (1985).

Many questions surround the evolution of institutions at the level of the plant and among groups of agents at the level of the industry and region. While some routines might be developed through deliberate search processes, others come about by trial and error. How economic agents or groups recognize particular routines, which routines are considered valuable and how routines become codified and shared among competing agents remains unclear.

Evolution of regions

When we shift attention away from the single region to consider competition among plants located in different regions, some interacting and some not, then place-specific characteristics become increasingly important to the performance of individual plants and to the regions in which they operate. And, once efficiency criteria become defined across regions, when previously independent selection environments merge, for example, then a new evolutionary dynamic develops that couples evolution *in* regions with the evolution *of* regions. It is to these issues that we now turn.

Where distances between regions are relatively large and transport costs sufficiently high, regional economies may evolve independently. Economic change within each region can be reduced to an analysis of population dynamics, and in a uniform selection environment, those dynamics are controlled largely by heterogeneity in the characteristics of individual agents. Of greater interest in this multi-region setting is the character of evolution in different places. Over time it is likely that economic agents located in different regions will develop distinct characteristics and routines, and that those regions themselves will become increasingly differentiated in terms of the mix of industries, the form and depth of institutions, organizational forms and other place-bound resources.

Saxenian (1994) and Gertler (2005) provide clear evidence of institutional variation between regions. Evidence of technological variations between regions is also clear. Learning processes, search and knowledge flows all tend to be highly localized (Arrow 1962, Lundvall 1988, Jaffe et al. 1993). This reflects familiarity with an existing knowledge base, technological interdependencies and network relations. Localization is also reinforced by sharply declining returns to investment in R&D efforts that are distant from existing technology and by steep distance decay effects as well as sharp discontinuities around the boundaries of specific knowledge bases. The geographical constraints on technology development suggest that technologies will evolve along relatively distinct pathways as the plants and firms of different regions follow innovatory trajectories conditioned by their history and geography (Sahal 1981; Dosi 1982; Clark 1985). Empirical evidence strongly confirms these claims (Habakkuk 1962; David 1975; Rigby and Essletzbichler 1997, 2006).

Figure 2 provides additional evidence of geographical variations in manufacturing technology across the US space economy. The top two panels of the figure show state differences in techniques of production in 1963 and 1992 in the US sheet metal work industry (SIC 3444). Technology is represented by a capital input coefficient and a labor input coefficient that locates plants, and in aggregate regions and entire industries, within a two-dimensional technology space (see Essletzbichler 1999). While there has been significant improvement in efficiency in this industry since 1963, regional differences in technology persist. The bottom left panel in the figure shows that many of the differences in technology between states in 1963 are statistically significant. Significance is assessed by comparing the distribution of plant technologies within a pair of states using multivariate analysis of variance. The dark shading indicates that the column state technology is not significantly different from the row state technology, while the light shading represents significant differences in techniques. There is evidence of broader regional clusters of technology, as the states are arranged in a rough geographic order. The lower right panel in Figure 2 establishes that differences in techniques of production between states tend to persist over time. The results in this panel show vector correlations that map the relative positions of states over 5-year periods. In all cases those correlations are positive and statistically significant.

Insert Figure 2 about here

If we conceive regions as selection environments, as spatial units that comprise economic agents (plants, workers, consumers) and the relations between those agents (social networks, input-output linkages, untraded interdependencies), all embedded within institutional environments (governance systems, business cultures) at least some of which are locally circumscribed, then it is likely that the economic performance of regions will vary because of differences in their characteristics. Exactly how regional fortunes might diverge is impossible to predict, as is the future of a specific region.

Regions are not static entities, however, they evolve over time as the endogenous population of economic agents and their characteristics shift, and as those agents deliberately try to influence the organizational and institutional environment within which they operate. That environment might be radically transformed by the development of new technologies that alter the friction of distance, or as institutional controls on borders and trade relax, redrawing the boundaries of the selection environment, perhaps exposing businesses to one another that formerly competed in separate spaces. In this way regions themselves might be considered as emergent properties of the process of capitalist competition. Indeed, as characteristic bundles of agents and place-specific attributes, regions increasingly become central to the strategies of economic agents, as spaces of contestation with resources to control, or when conditions dictate as spaces that can be remapped, shifting the boundaries of competition in particular directions.

The evolutionary arguments noted above have considerably enriched our understanding of the regional dimensions of technological change. Regions, like plants and firms, may be characterized by their variety in terms of technological, organizational, and informational characteristics. And, as in the economy more generally, technological progress and economic change at the regional level is shaped by the competitive processes that create and destroy variation and that select certain techniques and organizational forms over others. While these competitive pressures manifest themselves in various product markets and in the differential performance of plants, it would be wrong to view the performance of regions as nothing more than the performance of the business units that they contain. Stripped of their association with the social and institutional fabric that defines the familiar political-economy of a home space/local selection environment, even the most competitive plants might wither. With or without common histories of practice, once populations of plants become isolated, over time they will tend to develop different characteristics and exhibit increasingly distinct histories of development. These histories will shape the selection environment in which those plants are located, producing and reproducing regions with characteristics that emerge from the interplay of the forces of capitalist competition as well as from other social pressures.

It is clear today, as production becomes increasingly fragmented, that firms are paying more attention than ever to the characteristics of particular places as they search for more attractive sites of accumulation. This fragmentation of production is, at the same time, integrating regions across the world economy. This integration implies significant changes in the selection environments within which plants compete. Regions are no longer simple repositories of independent plants, other economic agents and local institutional forces that can be interpreted as the containers within

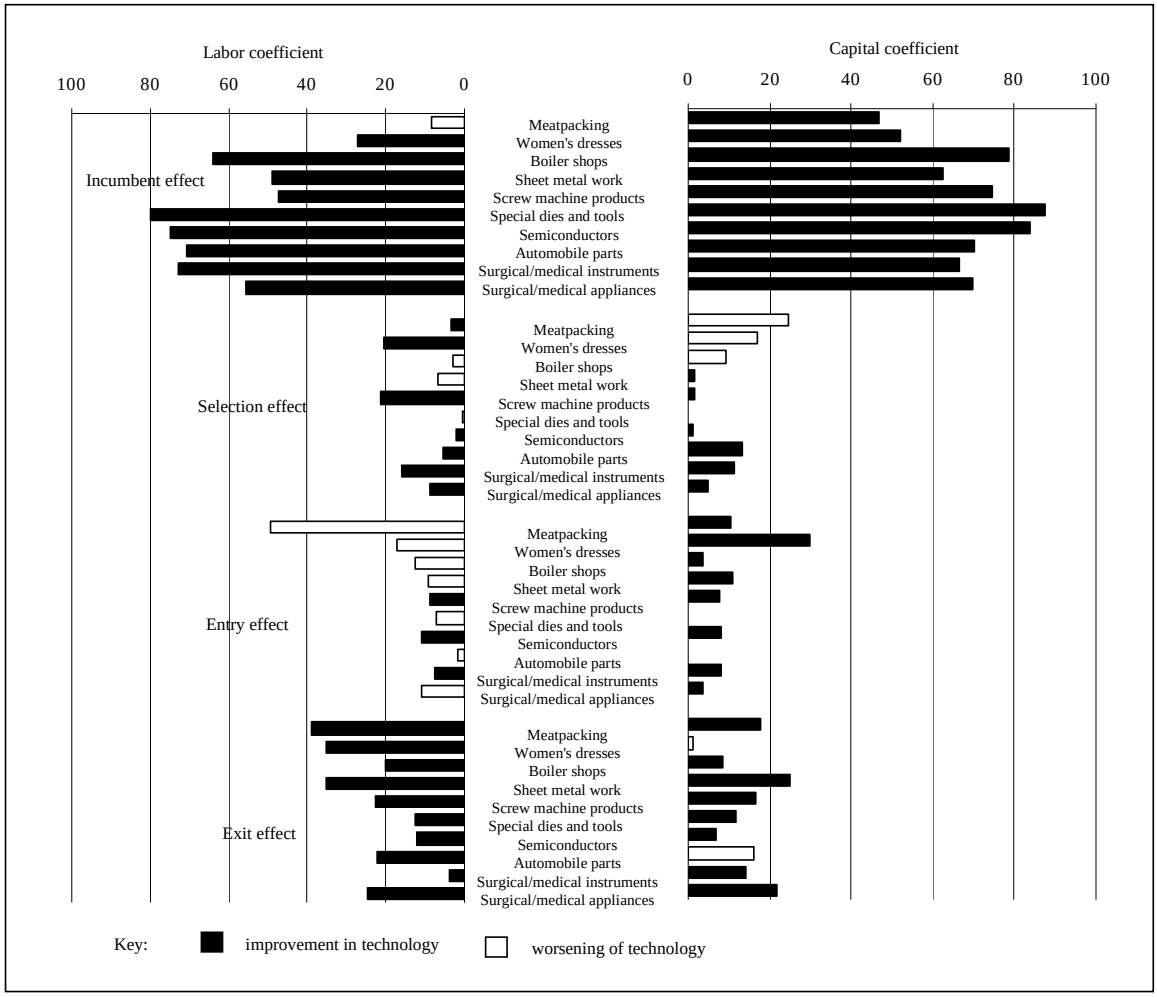
which competition works itself out. Rather, regions might be more accurately conceived as evolving bundles of attributes, some place-specific, others exotic, reflecting the inconstant population of economic agents in the region and the routines they have acquired through intra-firm and inter-firm networks that span multiple spaces. In this more complex environment, the processes of selection, of variety creation and destruction still function though it is a much more difficult task to show how they can be geographically isolated to account for the uneven development of regions. Indeed, individual plants now appear to be competing across a hierarchy of relatively unstable selection environments that span local, national and even global spaces. In some respects, perhaps, we might conceive of firms as creating their own "regional" selection environments through firm-specific divisions of labor across sectors and across spaces.

CONCLUSION

In this paper we argue that an explicit evolutionary approach offers a theoretically rich framework for analysis within economic geography. A number of different possible evolutionary vantage points were identified, though Generalized Darwinism seems to us to offer the most promise. Generalized Darwinism rests on the key evolutionary principles of variety, selection and continuity. The way that these processes operate within the domain of problems typically examined by economic geographers must be developed within that sub-field. While a number of researchers within economic geography have used evolutionary concepts and metaphors in their work, it is often unclear whether the broader arguments made are meant to capture an evolutionary dynamic, or indeed, whether they are even consistent with evolutionary theory at all. Without appreciation of that more general theory, use of terms such as path dependence, lock-in, selection or even evolution, lose much of their veracity.

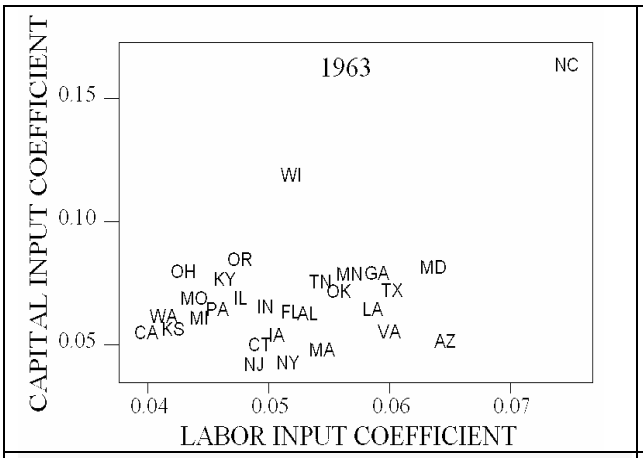
The appeal of evolutionary theory lies in its focus on dynamics and in its adoption of a population approach that celebrates the diverse characteristics and behaviors of individual agents and shows how macro-economic order can emerge from the seemingly chaotic actions of myriad competitors. That order does not have to be generated by appeals to perfect information and rationality, as in the core neoclassical arguments that underpin general equilibrium. Indeed, the notion of equilibrium, a system at rest, is antithetical to an evolutionary model of economic change, where uncertainty generates continuous experimentation and search for advantage. Geography plays a critical role in the evolutionary processes of variety creation and destruction, selection and continuity. Isolated regions allow unique selection environments to develop, routines and institutions that are specific to individual organizations and to the broader environment within which they operate. And, as the world economy becomes both increasingly fragmented and integrated, so new patterns of organization emerge from the search to exploit spatial differences in the possibilities of accumulation. As competition unfolds over time, so new spaces of economic activity are created. Regions as different assemblages of production and consumption possibilities, of organizational forms and institutional variety are pulled together and broken apart, re-ordering hierarchies of performance only to generate new patterns of interaction.

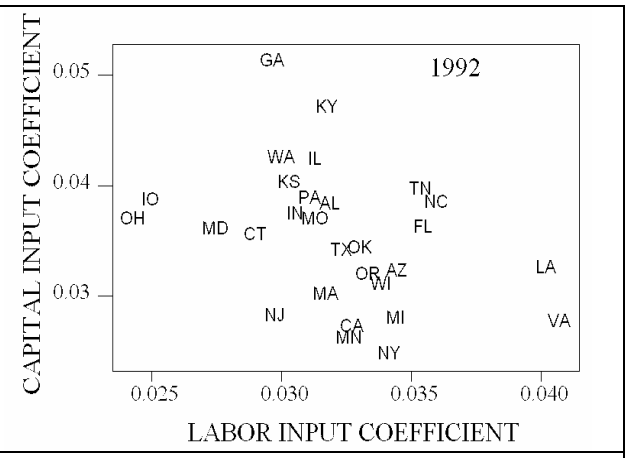
Figure 1: Components of Change in Techniques of Production, Selected US (4-digit SIC) Manufacturing Industries, 1963-1992

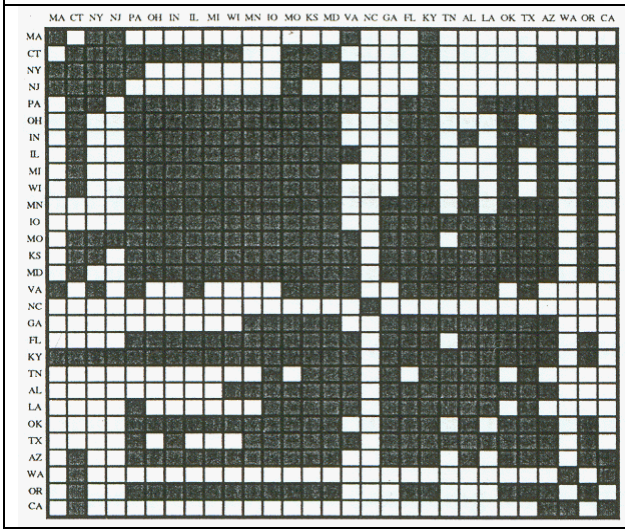


Notes: Sources of data, definitions of variables and techniques of measurement are provided in Rigby and Essletzbichler (2005).

Figure 2: Regional Differences in Techniques of Production







YEAR	N	VECTOR CORRLTN	T
1963-67	29	0.506	3.050
1967-72	29	0.677	4.775
1972-77	29	0.474	2.801
1977-82	29	0.562	3.532
1982-87	29	0.568	3.583
1987-92	29	0.578	3.677

Notes: Definitions of variables, sources of data and methods used are summarized in Essletzbichler 1999
The top two panels show the location of individual states in a two-dimensional technology space. The state abbreviations are explained below. The bottom left panel indicates whether pairs of states have technologies that are significantly different at the 0.05 level using a multi-variate analysis of variance test: white squares indicate pairs of states that have significantly different technologies. The states in this panel are loosely arranged in geographic order by census region. The bottom right panel indicates the results of t-tests from vector correlations. All correlations are positive and significantly different from zero at the 0.05 level. State abbreviations: MA = Massachusetts, CT = Connecticut, NY = New York, NJ = New Jersey, PA = Pennsylvania, OH = Ohio, IN = Indiana, IL = Illinois, MI = Michigan, WI = Wisconsin, MN = Minnesota, IO = Iowa, MO = Missouri, KS = Kansas, MD = Maryland, VA = Virginia, NC = North Carolina, GA = Georgia, FL = Florida, KY = Kentucky, TN = Tennessee, AL = Alabama, LA = Louisiana,
OK = Oklahoma, TX = Texas, AZ = Arizona, WA = Washington, OR = Oregon, CA = California.

REFERENCES

Abernathy, W.J., Utterback, J.M. (1978) Patterns of Industrial Innovation. *Technology Review*, 80: 40-47.

Alchian, A. (1950) Uncertainty, Evolution and Economic Theory. *Journal of Political Economy,* 58: 211-222.

Amin, A. (1999) An Institutionalist Perspective on Regional Economic Development. *International Journal of Urban and Regional Research,* 23: 365-378.

Amin, A. (2001) Moving on: Institutionalism in Economic Geography. *Environment and Planning A,* 33: 1237-1241.

Amin, A. Thrift, N (1994) Living in the global. In A., Amin and N. Thrift (eds) *Globalization, Institutions, and Regional Development in Europe*. Oxford: Oxford University Press: 1-22.

Andersen, E. (1994) *Evolutionary Economics: Post Schumpeterian Contributions*. London: Pinter.

Andersen, E. (2004) *Population Thinking, Price's Equation and the Analysis of Economic Evolution*. Paper submitted to Evolutionary and Institutional Economics Review.

Arrow, K. (1962) The Economic Implications of Learning by Doing. *Review of Economic Studies*, 29: 22-43.

Arthur, B. (1983) On Competing Technologies and Historical Events Small Events: The Dynamics of Choice under Increasing Returns. Working Paper WP-83-90. *International Institute for Applied Systems Analysis (IIASA),* Vienna.

Arthur, B. (1989) Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *Economic Journal*, 99: 116-131.

Arthur, B. (1994): *Increasing Returns and Path Dependence in the Economy*. Ann Arbor: The University of Michigan Press.

Audretsch, D.B. (1995) *Innovation and Industry Evolution*. Cambridge MA, MIT Press.

Baldwin, J.R. (1995): *The Dynamics of Industrial Competition*. Cambridge UK: Cambridge University Press.

Barnes, T. (1997) Theories of Accumulation and Regulation: Bringing Back Life to Economic Geography. In R. Lee and J. Wills (eds) *Geographies of Economies*, London: Arnold, 231-24.

Bartelsman, E., Doms, M. (2000) Understanding Productivity: Lessons from Longitudinal Microdata. *Journal of Economic Literature*, *38*: 569-594.

Becker, G. (1976) *The Economic Approach to Human Behavior*. Chicago: The University of Chicago Press.

Boschma, R. A. (2004) Competitiveness of Regions from an Evolutionary Perspective. *Regional Studies,* 38: 1001-1014.

Boschma, R., Lambooy, J. (1999) Evolutionary Economics and Economic Geography. *Journal of Evolutionary Economics:* 411-429.

Boschma, R., Frenken, K. (2006) Why is Economic Geography not an Evolutionary Science? Towards an Evolutionary Economic Geography. *Journal of Economic Geography*, 6: 273-302.

Boschma, R., Van der Knaap, G.A. (1997), New Technology and Windows of Locational Opportunity: Indeterminacy, Creativity and Chance. In Reijnders, J. (ed), *Economics and Evolution*. Cheltenham UK and Lyme US: Edward Elgar, 171-202..

Boschma, R., Wenting, R. (2007) The Spatial Evolution of the British Automobile Industry. Does Location Matter? *Industrial and Corporate Change*, in press.
Bottazzi, G., Dosi, G., Fagiolo, G. and A. Secchi (2007) Modeling Industrial Evolution in Geographical Space. *Journal of Economic Geography*, this special issue.
Braczyk, H.-J., Cooke, P., Heidenreich, M. (1998) *Regional Innovation Systems*. London: UCL Press.
Brusco, S. (1982): The Emilian Model: Productive Decentralization and Social Integration. *Cambridge Journal of Economics*, 6: 167-184.
Bryant, K. (2001) Promoting Innovation: An Overview of the Application of Evolutionary Economics and Systems Approaches to Policy Issues. In Foster, J. and S. Metcalfe (eds) *New Frontiers in Evolutionary Economics*. Cheltenham: Edward Elgar: 361-383.
Cantner, U., and Hanusch, H. (2001). Heterogeneity and Evolutionary Change: Empirical Conception, Findings and Unresolved Issues. In J. Foster and J. S. Metcalfe (eds), *New Frontiers in Evolutionary Economics*. Cheltenham UK and Northampton MA: Edward Elgar: 228-269.
Clark, K.B. (1985): The Interaction of Design Hierarchies and Market Concepts in Technological Evolution. *Research Policy*, 14: 235-251.
Cohen, W. M., Levinthal, D. A (1989) Innovation and Learning: The Two Faces of R&D. *Economic Journal*, 99: 569-596.
Cooke, P., Morgan, K. (1998) *The Associational Economy: Firms, Regions and Innovation*, Oxford: Oxford University Press.
Coricelli, F., Dosi, G. (1988) Coordination and Order in Economic Change and the Interpretative Power of Economic Theory. In G. Dosi, C. Freeman, R. Nelson, G. Silberberg, L., Soete (eds) *Technical Change and Economic Theory.* London and New York: Pinter: 124-147.
David, P. (1975) *Technical Choice, Innovation and Economic Growth*. London: Cambridge University Press.
David, P. (1985) Clio and the *E*conomics of QWERTY. *American Economic Review, Proceedings, 75*: 332-337.
David, P. (1992): Heroes, Herds and Hysteresis in Technological History: Thomas Edison and 'The Battle of Systems" Reconsidered. *Industrial and Corporate Change*, 1: 129-180.
Dawkins, R. (1976) The Selfish Gene. Oxford: Oxford University Press.
Depew, D.J, Weber, B.H. (1995): *Darwinism Evolving*. Cambridge MA and London: MIT Press.
Depew, D.J. and B.H. Weber (1996) Natural Selection and Self-Organization. *Biology and Philosophy*, 11: 33-65.
Dosi, G. (1982): Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change. *Research Policy*, 11: 147-162.
Dosi, G. (1988) Sources, Procedures and Microeconomic Effects of Innovation. *Journal of Economic Literature, 26*: 1120-1171.
Dosi, G. (1997) Opportunities, Incentives and the Collective Patterns of Technological change. *Economic Journal, 107*: 1530-1547.
Dosi, G., Freeman, C., Nelson, R., Silberberg, G., Soete, L. (eds) *Technical Change and Economic Theory.* London and New York: Pinter

Dosi, G., Metcalfe, J.S. (1991): On Some Notions of Irreversibility in Economics. In: P. Saviotti and J.S. Metcalfe (eds.): *Evolutionary Theories of Economic and Technological Change: Present Status and Future Prospects*. Chur: Harwood Academic Publishers: 133-159.

Dosi, G., Nelson, R. (1994) An Introduction to Evolutionary Theories in Economics. *Journal of Evolutionary Economics, 4*: 153-172.

Duranton, G., Puga, D. (2001) Nursery cities: urban diversity, process innovation and the life-cycle of products. *American Economic Review*, 91: 1454-1477.

Durham, W.H. (1991) *Coevolution: Genes, Culture, and Human Diversity*. Stanford: Stanford University Press.

Edquist, C. (ed)(1997): *Systems of Innovation. Technologies, Institutions and Organizations*. London and Washington: Pinter.

Edquist, C., Johnson,B. (1997): Institutions and Organizations in Systems of Innovation. In Edquist (ed): *Systems of Innovation*. London and Washington: Pinter: 41-63.

Endler, , J.A., McLellan, T. (1988) The Process of Evolution: Towards a New Synthesis. *Annual Review of Ecological Systematics*, 19: 395-421.

Essletzbichler, J. (1999) *Regional Differences in Technology Evolution in US Manufacturing.* Unpublished PhD dissertation. University of California Los Angeles: Los Angeles.

Essletzbichler, J. and H. Gassler (1996): Regionalisierte Technologiepolitik in einer globalen Ökonomie. *Kurswechsel*, Heft 2: 35-48.

Essletzbichler, J., Rigby, D. (2005a) Technological Evolution as Creative Destruction of Process Heterogeneity. Evidence from US Plant Level Data. *Economic Systems Research*, 17: 25-45.

Essletzbichler, J., Rigby, D. (2005b) Competition, Variety and the Geography of Technology Evolution. *Tijdschrift voor Economische en Sociale Geografie,* 96: 48-62.

Farjoun, E., Machover, M. (1983). *Laws of Chaos - a Probabilistic Approach to Political Economy*. London: Verso.

Fincher, R. (1983) The Inconsistency of Eclecticism. *Environment and Planning A*, 15: 607-622.

Fisher, R.A. (1930) The Genetical Theory of Natural Selection.

Foster, J. (1997) The Analytical Foundations of Evolutionary Economics: From Biological Analogy to Economic Self-Organization. *Structural Change and Economic Dynamics*, *8*: 427-451.

Foster, J. (2000) Competitive selection, self-organization and Joseph A. Schumpeter. *Journal of Evolutionary Economics,* 10: 311-328.

Foster, J. (2001) Competition, Competitive Selection and Economic Evolution. In P. Garrouste and S. Ioannides (eds) *Evolution and Path Dependence in Economic Ideas*. Cheltenham and Northampton: Edward Elgar: 107-132.

Foster, J. and Metcalfe, S. (2001). Modern Evolutionary Economic Perspectives: An Overview. In J. Foster and J. S. Metcalfe (eds) *Frontiers of Evolutionary Economics.* Cheltenham, UK and Northampton, MA: Edward Elgar: 1-16.

Fujita, M., Krugman, P. and T. Venables (1999) *The Spatial Economy: Cities, Regions and International Trade*. Cambridge MA: MIT Press.

Freeman, C. (1995): The "National System of Innovation" in Historical Perspective. *Cambridge Journal of Economics*, 19: 5-24.

Frenken, K. and Boschma, R.A. (2007): A Theoretical Framework for Evolutionary Economic Geography. Industrial Dynamics and Urban Growth as a Branching Process. *Journal of Economic Geography*, this special issue.
Friedman, M. (1953): *Essays in Positive Economics*. University of Chicago Press, Chicago.
Gertler, M. (2005) *Manufacturing Culture: The Governance of Industrial Practice*. Oxford: Oxford University Press.
Gort, M., Klepper, S. (1982): Time Paths in the Diffusion of Product Innovations. *Economic Journal*, 92: 630-653.
Gould, S.J., Vrba, E.S. (1982): Exaptation - A Missing Term in the Science of Form. *Paleobiology*, 8: 4-15.
Gowdy, J.M. (1992): Higher Selection Processes in Evolutionary Economic Change. *Journal of Evolutionary Economics*, 2: 1-16.
Gowdy, J.M. (1994): *Coevolutionary Economics: The Economy, Society and the Environment*. Kluwer Academic Publishers, Boston.
Grabher, G. (1993): The Weakness of Strong Ties - The Lock-In of Regional Development in the Ruhr Area. In G. Grabher (ed.) In *The Embedded Firm*. London: Routledge: 255-277.
Grabher, G., Stark, D. (1997): Organizing Diversity: Evolutionary Theory, Network Analysis and Postsocialism. *Regional Studies*, 31: 533-544.
Granovetter, M. (1973) The Strength of Weak Ties. *American Journal of Sociology*, 78: 360-380.
Granovetter, M. (1985): Economic Action and Social Structure: The Problem of Embeddedness. *American Journal of Sociology*, 91: 481-510.
Gregersen, B., Johnson, B. (1997): Learning Economies, Innovation Systems and European Integration. *Regional Studies*, 31: 479-490.
Griliches, Z. (1957): Hybrid Corn: An Exploration in the Economics of Technological Change. *Econometrica*, 25: 501-523.
Habbakuk, H.J. (1962) *American and British Technology in the 19th Century*. Cambridge: Cambridge University Press.
Hanappi, G. (1995): *Evolutionary Economics. The Evolutionary Revolution in the Social Sciences*. Avebury, Aldershot.
Hartley, J. (1997) *The Representative Agent in Macroeconomics*. London and New York: Routledge.
Harvey, D. (1982) *The Limits to Capital*. Basil Blackwell, Oxford.
Hassink, R. (2005) How to Unlock Regional Economies from Path Dependency? From Learning Region to Learning Cluster. *European Planning Studies*, 13: 521-535.
Hirschleifer, J. (1977) Economics from a Biological Viewpoint. *Journal of Law and Economics*, 20: 1-52.
Hodgson, G. (1988) *Economics and Institutions*. Cambridge: Polity Press.
Hodgson, G. (1993): *Economics and Evolution. Bringing Life Back into Economics*. Oxford: Polity Press.
Hodgson, G. (2001): *How Economics Forgot History. The Problem of Historical Specificity in Social Science*. London and New York: Routledge.
Hodgson, G. (2001) Is Social Evolution Lamarckian or Darwinian? In J. Laurent, J. Nightingale (eds) *Darwinism and Evolutionary Economics*. Cheltenham: Edward Elgar: 87-118.

Hodgson, G. (2002) Darwinism in Economics: From Analogy to Ontology. *Journal of Evolutionary Economics*, 12: 259-281.
Hodgson, G. (2004) Darwinism, Causality and the Social Sciences. *Journal of Economic Methodology*, 11: 175-194.
Hodgson, G., Knudsen, T. (2004) The Firm as an Interactor: Firms as Vehicles for habits and Routines. *Journal of Evolutionary Economics*, 14: 281-307.
Hoover, E.M. (1948) *The Location of Economic Activity*. New York: McGraw Hill.
Hudson, R. (1999) The Learning Economy, the Learning firm and the Learning Region: A Sympathetic Critique of the Limits to Learning. *European Urban and Regional Studies*, 6: 59-72.
Hudson, R. (2001) *Producing Places*. Guilford: Guilford Press.
Iwai, K. (1984a): Schumpeterian Dynamics. An Evolutionary Model of Innovation and Imitation. *Journal of Economic Behavior and Organization,* 5: 159-190.
Iwai, K. (1984b): Schumpeterian Dynamics, Part II: Technological Progress, Firm Growth and 'Economic Selection. *Journal of Economic Behavior and Organization*, 5: 321-351.
Jaffe, A.B., Trajtenberg, M. and R. Henderson (1993) Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics*, 108: 577-598.
Jessop, B. (2001) Institutional Re(turns) and the Strategic-Relational Approach. *Environment and Planning A*, 33: 1213-1235.
Jevons, W.S. (1871) *The Theory of Political Economy*. London: Macmillan.
Kaufmann, S. (1993) *The Origins of Order: Self-Organization and Selection in Evolution*. New York: Oxford University Press.
Kirman, A. (1992a) Variety: The Coexistence of Techniques. *Revue D'Economie Industrielle*, 59: 62-74.
Kirman, A. (1992b) Whom or What Does the Representative Individual Represent? *Journal of Economic Perspectives*, 6: 117-136.
Klepper, S. (1996) Entry, Exit, Growth, and Innovation over the Product Life Cycle. *American Economic Review*, 86: 562-583.
Klepper, S. (2001) The Capabilities of New Firms and the Evolution of the U.S. Automobile Industry. *Industrial and Corporate Change*, 11: 645-666.
Klepper, S., Graddy, E. (1990): The Evolution of New Industries and the Determinants of Market Structure. *Rand Journal of Economics*, 21: 27-44.
Klepper, S., Simons, K.L. (2000) The Making of an Oligopoly: Firm Survival and Technological Change in the Evolution of the US Tire Industry. *Journal of Political Economy*, 108: 728-760.
Knudsen, T. (2002) Economic Selection Theory. *Journal of Evolutionary Economics*, 12: 443-470.
Knudsen, T. (2004) General Selection Theory and Economic Evolution: The Price Equation and the Replicator/Interactor Distinction. *Journal of Economic Methodology*, 11: 147-173.
Krugman, P. (1991b): Increasing Returns and Economic Geography. *Journal of Political Economy*, vol. 99, pp. 483-499.
Lawson, C. (1999), Towards a Competence Theory of the Region. *Cambridge Journal of Economics*, 23: 151-166.
Lawson, T. (2006) The Nature of Heterodox Economics. *Cambridge Journal of Economics*, 30: 483-505.

Levins, R. and R. Lewontin (1985): *The Dialectical Biologist*. Cambridge, MA: Cambridge University Press.
Lewontin, R.C. (1970) The units of selection. *Annual Review of Ecology and Systematics*, 1: 114.
Lundvall, B.A. (1988): Innovation as an interactive process: From User-Producer Interaction to the National System of Innovation. In Dosi, G., Freeman, C., Nelson, R., Silberberg, G., Soete, L. (eds) *Technical Change and Economic Theory.* London and New York: Pinter: 349-369.
Marshall, A. (1920) *The Principles of Economics*. (8 ed.). London: MacMillan.
Martin, R. (1999) The New 'Geographical Turn' in Economics: Some Critical Reflections. *Cambridge Journal of Economics*, 23: 65-91.
Martin, R. (2000) Institutional approaches in economic geography. In E. Sheppard and T. Barnes (eds) *A Companion to Economic Geography*. Oxford: Blackwell**:** 77-94.
Martin, R., Sunley, P. (2006) Path dependence and regional economic evolution *Journal of Economic Geography*, 6: 395-437.
Maskell, P., Malmberg, A. (1999) Localized Learning and Industrial Competitiveness, *Cambridge Journal of Economics*, 23: 167-185.
Maskell, P., Malmberg, A. (2007) Myopia, Knowledge Development and Cluster Evolution, *Journal of Economic Geography*, this special issue.
Massey, D. (1984) *Spatial Divisions of Labor: Social Structures and the Geography of Production*. Macmillan: London.
Mayr, E. (1982) *The Growth of Biological Thought: Diversity, Evolution, and Inheritance*. Cambridge, MA: Harvard University Press.
Mayr, E. (1984) Typological versus Population Thinking. In E. Sober (ed) *Conceptual Issues in Evolutionary Biology: An Anthology*. Cambridge, MA: MIT Press.
Metcalfe, S. (1998) *Evolutionary Economics and Creative Destruction*. London and New York: Routledge.
Metcalfe, S. (2005) Evolutionary Concepts in Relation to Evolutionary Economics. In K. Dopfer (ed) *The Evolutionary Foundations of Economics*. Cambridge: Cambridge University Press: 391-430.
Metcalfe, S., Gibbons, M. (1986) Technological Variety and the Process of Competition. *Economie Appliquée, 39*: 493-520.
Metcalfe, J., Foster, J. Ramlogan, R. (2006) Adaptive Economic Growth. *Cambridge Journal of Economics*, 30: 7-32.
Montobbio, F. (2000) An Evolutionary Model of Industrial Growth and Structural Change. *Center for Research on Innovation and Competition Discussion Paper No 34*. Manchester, The University of Manchester.
Nelson, R. (1995) Recent Evolutionary Theorizing about Economic Change. *Journal of Economic Literature, 33*: 48-90.
Nelson, R. (2001). The coevolution of technology and institutions as the driver of economic growth. In J. Foster and S. Metcalfe (eds): *Frontiers in Evolutionary Economics*. Cheltenham and Northampton: Edward Elgar**:** 19-30.
Nelson, R.R. and S. Winter (1974): Neoclassical and Evolutionary Theories of Growth: Critique and Prospectus. *Economic Journal*, 84: 886-905.
Nelson, R., Winter, S. (1982) *An Evolutionary Theory of Economic Growth*. Cambridge, MA: Harvard University Press.

Pavitt, K. (2005) Innovation Processes. In J. Fagerberg, D.C. Mowery and R.Nelson (eds) The Oxford Handbook of Innovation, Chapter 4. Oxford: Oxford University Press.
Peck, J. (2005) Economic Sociologies in Space. *Economic Geography*, 81: 129-175.
Rigby, D., Essletzbichler, J. (1997) Evolution, Process Variety, and Regional Trajectories of Technological Change in U.S. Manufacturing. *Economic Geography, 73*: 269-284.
Rigby, D., Essletzbichler, J. (2000) Impacts of Industry Mix, Technological Change, Selection and Plant Entry/Exit on Regional Productivity Growth. *Regional Studies, 34*: 333-342.
Rigby, D., Essletzbichler, J. (2006) Technological Variety, Technological Change and a Geography of Production Techniques. *Journal of Economic Geography*, 6: 45-70.
Price, G.R. (1970) Selection and Covariance. *Nature*, 227: 520-521.
Sahal, D. (1981): *Patterns of Technological Innovation*. Addison Wesley, Reading MA.
Saviotti, P. (1991). The Role of Variety in Economic and Technological Development. In P. Saviotti, S. Metcalfe (eds) *Evolutionary Theories of Economic and Technological Change.* Chur: Harwood Academic Publishers: 172-208.
Saviotti, P. (1996) *Technological Evolution, Variety and the Economy*. Cheltenham: Edward Elgar.
Saviotti, P., Metcalfe, S. (1991) *Evolutionary Theories of Economic and Technological change*. Chur, Switzerland: Harwood Academic Publishers.
Saviotti, P., Pyka, A. (2001) Economic Development by the Creation of New Sectors. *Journal of Evolutionary Economics*, 14: 1-36.
Saxenian, A. (1994): *Regional Advantage*. Harvard University Press, MA.
Schumpeter (1939): *Business Cycles*. McGraw hill, London).
Schumpeter, J. (1942) *Capitalism, Socialism and Democracy*. New York: Harper and Row.
Scott, A.J. (1988): *Metropolis: From the Division of Labor to Urban Form*. University of California Press, Berkeley.
Scott, A.J. (2006) Geography and Economy. Oxford: Oxford University Press.
Setterfield, M. (1993) A Model of Institutional Hysteresis. Journal of Economic Issues, 27: 755-774.
Sheppard, E. (2000) Geography or Economics? Conceptions of Space, Time, Interdependence and Agency. In G. Clark, M. Feldman, M. Gertler (eds) *The Oxford Handbook of Economic Geography*. Oxford: Oxford University Press.
Simon, H. (1957) *Models of Man*. New York: John Wiley.
Sober, E. (1984): *The Nature of Selection: Evolutionary Theory in Philosophical Focus*. MIT Press, Cambridge MA.
Sober, E., Wilson, D.S. (1998) *Unto Others: The Evolution and Psychology of Unselfish Behavior*. Cambridge MA: Harvard University Press.
Storper, M. (1997): *The Regional World*. Guilford Press, New York.
Utterback, J.M., Abernathy, W.J. (1975): A Dynamic Model of Product and Process Innovation. *Omega*, 3: 639-656.
Utterback, J.M., Suarez, F.F. (1993) Innovation, Competition and Industry Structure. *Research Policy*, 22: 1-21.

Veblen, T. (1898) Why is Economics not an Evolutionary Science? *Quarterly Journal of Economics*, 12: 373-397.
Veblen, T. (1899) (1994ed.) *The Theory of the Leisure Class*. New York: Dover.
Verspagen, B. (2001) *Economic Growth and Technological Change: An Evolutionary Interpretation* (STI Working paper 2001/1). Paris: OECD, Directorate for Science, Technology and Industry
Vrba, E. S., Gould, S.J. (1986) The hierarchical expansion of sorting and selection: sorting and selection cannot be equated. *Paleobiology*, 10: 217-228.
Vromen, J. (1995) *Economic Evolution: An Enquiry in the Foundations of New Institutional Economics*. London: Routledge.
Vromen, J. (2001) The Human Agent in Evolutionary Economics. In J. Laurent and J. Nightingale (eds) *Darwinism and Evolutionary Economics*, Cheltenham: Edward Elgar, 184-208.
Vromen, J. (2004) Conjectural Revisionary Economic Ontology: Outline of an Ambitious Research Agenda for Evolutionary Economics. *Journal of Economic Methodology*, 11: 213-247.
Walras, L. (1926) *Elements of Pure Economics*. London: George Allen and Unwin.
Weber, A. (1929) *Theory of the Location of Industries*. Chicago: The University of Chicago Press.
Webber, M., Sheppard, E., Rigby, D. (1992) Forms of Technical Change.
Environment
and Planning A, 24: 1679-1709.
Wilson, E.O. (1975) *Sociobiology: The New Synthesis*. Cambridge MA, Belknap Press.
Winter, S.G., Kaniovski, Y., Dosi, G. (2003) A Baseline Model of Industrial Evolution. *Journal of Evolutionary Economics*, 13: 355-383.
Witt, Ulrich (2002) 'How Evolutionary is Schumpeter's Theory of Economic Development?', *Industry and Innovation*, 9(1/2): 7-22.
Witt, U. (2004) On the Proper Interpretation of "Evolution" in Economics and its Implications for Production Theory. *Journal of Economic Methodology*, 11: 125-146.