Evolutionary Macroeconomics: A Research Agenda

John Foster

The challenge to an evolutionary formation is this: it must provide an analysis that at least comes close to matching the power of the neoclassical theory to predict and illuminate the macro-economic patterns of growth

Nelson and Winter (1982), p. 206

Abstract In this article, the goal is to offer a new research agenda for evolutionary macroeconomics. The article commences with a broad review of the main ideas in the history of thought concerning the determinants of economic growth and an introduction to the evolutionary perspective. This followed by a selective review of recent evolutionary approaches to macroeconomics. These approaches are found to be somewhat disconnected. It is argued that the 'micro-meso-macro' approach to economic evolution is capable of resolving this problem by offering an analytical framework in which macroeconomics can be built upon 'meso-foundations', not micro-foundations, as asserted in the mainstream. It is also stressed that the economic system and its components are complex adaptive systems and that this complexity must not be assumed away through the imposition of simplistic assumptions made for analytical convenience. It is explained that complex economic systems are, at base, energetic in character but differ from biological complex systems in the way that they collect, store and apply knowledge. It is argued that a focus upon stocks and flows of energy and knowledge in complex economic systems can yield an appropriate analytical framework for macroeconomics. It is explained how such a framework can be connected with key insights of both Schumpeter and Keynes that have been eliminated in modern macroeconomics. A macroeconomic framework that cannot be operationalized empirically is of limited usefulness so, in the last part of the article, an appropriate methodology for evolutionary macroeconomics is discussed.

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1 Introduction

Modern evolutionary economics has tended to be concerned with supply side questions, posed at the firm or industry level. This supply-side focus has been difficult to connect, both analytically and empirically, with macroeconomics. The upshot is that the literature on evolutionary macroeconomics is relatively sparse and not set within a widely accepted methodological framework. The purpose of this article is to appraise why this is the case and to offer a research agenda that might rectify the situation. Given the widespread failure of mainstream macroeconomists to offer warnings of the recent global crisis or any innovative prescriptions to deal with it, the further development of evolutionary macroeconomic analysis would seem to be very timely.

In discussing this agenda, the focus will be squarely on the process of economic growth and its fluctuations, which is the appropriate macroeconomic context when we are dealing with economic evolution. Growth and cycles have also been the main focus of mainstream macroeconomics over the past decade, so direct comparisons can be made. In Sect. 2, we begin with a broad review of the main ideas in the history of thought concerning the determinants of economic growth and an introduction to the evolutionary perspective. Having set the scene, in Sect. 3 we look briefly at how evolutionary economists have tried to deal with the macroeconomic level of enquiry. In Sect. 4, we summarise the micro-meso-macro perspective on evolutionary economics and argue that evolutionary macroeconomics should be built upon meso-foundations, not micro-foundations, as asserted in the mainstream. In Sect. 5, it is argued that we must acknowledge fact that the economic system and its components are complex adaptive systems and, as such, they have an energetic character that must be dealt with explicitly, particularly if environmental interactions are to be understood. Section 6 outlines an appropriate macroeconomic framework that can embrace the intuitions of both Schumpeter and Keynes. Section 7 discusses what kind of methodology we can apply to engage in empirical evolutionary macroeconomics and Sect. 8 contains some concluding remarks.

2 Economic Growth and Economic Evolution

One of the great challenges that economists have had to face for many decades is to offer a theory of economic growth that is capable of addressing the historical record as detailed, for example, in the meticulously constructed time series collected by Angus Maddison (2007). Historians of economic growth such as Walt Rostow, Douglass North, Joel Mokyr and Paul David have told us that economic growth is driven by processes of invention, entrepreneurship, technological and organizational innovation, education, training and experience (learning by doing). They have also told us that growth is both facilitated and constrained by institutions and that institutional change is an essential driver of economic growth.

Although it is quite easy to understand intuitively why these factors are important and historians have provided many supporting case studies, mainstream economists have found it difficult to construct models of economic growth that can identify the relative contributions of each driver. In conventional economics, economic theory is, in the main, microeconomic theory and macroeconomics involves aggregation from 'representative agent' micro-foundations. Now, although modern microeconomics spans both individual constrained optimisation (neoclassical economics) and strategic constrained optimisation (game theory), the former is preferred because it is possible to make formal aggregative connections with macroeconomic behaviour. However, this involves very strong assumptions that, in effect, conflate macroeconomic theory to be microeconomic theory. So it is commonplace to construct a theoretical economy containing only one individual agent and one firm that optimize along very well-behaved utility and production functions.

Real business cycle theory is, of course, the most extreme example of this 'simplistic' approach (Foster 2005) to dealing with a complex system but it is also in evidence in more compelling, at least at a superficial level, endogenous theories of economic growth. Because of this, such theories have not been able to address the historical evidence in any direct sense. This is because any theory which is timeless in construction and, therefore, subject to a very restrictive set of unrealistic assumptions, such as time reversibility, cannot be connected formally with streams of historical economic data. This is very well understood by economic historians so it is puzzling as to why economists have persisted in using neoclassical constrained optimisation theory in constructing models of economic growth.

Slavish adherence to neoclassical constrained optimisation theory is a relatively modern phenomenon. In the field of growth theory, it dates back to the 1950s and particularly the work of Robert Solow, for which he was awarded a Nobel Prize. Earlier in the Twentieth Century, when neoclassical economics was still relatively young and much more Marshallian, many economists saw clearly that it would not be possible to have a viable theory of economic growth based upon neoclassical economic principles. Alfred Marshall himself did not have much to offer with regard to theorizing about economic growth except to say that it should be based upon some kind of evolutionary thinking (see Raffaelli 2003). The seminal contribution was to come from Roy Harrod who offered an analytical framework that did not rely upon the equilibrium approach of neoclassical economics to individual and firm behaviour (see Harrod 1948). Employing a dynamic mathematical approach, he depicted economic growth as a disequilibrium process with 'knife edge' temporary equilibria. Thus, economic growth was characterised as an unstable, endogenous process largely driven by the expectations and aspirations of business investors and endogenous system dynamics.

Like the analysis of Maynard Keynes, Harrod's theory was explicitly macroeconomic in orientation, focusing upon aggregates, such as saving and investment, and systemic flows of expenditure and income through multipliers and accelerators. Clearly, just as the Great Depression had influenced Keynes' macroeconomics, so Harrod had in mind the fluctuating growth observed in Britain in the Nineteenth Century and the first half of the Twentieth Century. He saw both growth and fluctuations as the product of a combination of exogenous and endogenous factors in varying measure.

The other non-neoclassical approach to economic growth in the pre-WWII era was, of course, that of Joseph Schumpeter which he framed early in his career in his *Theory of Economic Development* (1912:1934). His analytical representation of the process of economic growth was very different to that of Harrod – it involved a quite distinct evolutionary process of 'creative destruction'. However, they did share the view that the imaginative aspirations of the business community are fundamental in the process of economic growth and its fluctuation and that entrepreneurial behaviour in a state of uncertainty cannot be captured in a neoclassical model. Schumpeter, instead, gave a key role to the process of competitive selection in determining how best practice and best products emerged. This kind of thinking was absent in Harrod's theory, which centred upon the aggregate balance of saving, investment and population change. Unlike Harrod, Schumpeter did not provide a mathematical representation of his theory because he saw it as, inherently, about structural change in a historical continuum. The clear ontological difference between these two theories has meant that there have been very few attempts to integrate them. An exception is Ertürk (2002), who argued that they are compatible in a number of respects and he shows how aspects of Schumpeter's theory can be included in a modified Harrod growth model.

Both Harrod and Schumpeter's depictions of economic growth, in retrospect, seem revolutionary but, in point of fact, they both reflected long traditions in economics whereby conventional equilibrium analysis was reserved for short period and local settings while the long period was seen as driven by historical tendencies which are non-equilibrium in character. This was very much the position held by Alfred Marshall – the notion of 'long run equilibrium' was of analytical interest but it this was not to be confused with a proper understanding of the economy in the 'long period' (Foster 1993). In his view, constrained optimization is practised when it is feasible but this was always seen as being subject to historical constraints and boundaries placed on knowledge and action by the social, cultural and legal rules that prevailed. In other words, economic behaviour is always subject to historical contingency, individual and collective knowledge and the institutional fabric.

Most classical economists used, as an analytical device, the notion of a long-run equilibrium that was built, in the Newtonian style, upon the manageable comparative static equilibrium method. The focus was not on the behaviour of individuals but on socio-political groups and the goal was not empirical (this was the accepted domain of historians) but the establishment of theoretical principles that could address policy-making. For example, the abolition of the Corn Laws in England in 1846 was inspired by classical theorising, particularly that of David Ricardo. By the mid Twentieth Century, classical economics was still in evidence but in direct competition with neoclassical economics and, correspondingly, there arose two very distinct long-run equilibrium challenges to the non-equilibrium theories of Harrod and Schumpeter.

The Classical approach to economic growth was developed in Cambridge mainly by Nicholas Kaldor, Joan Robinson and Luigi Pasinetti. It is a distributional model of economic growth with Keynesian features, inspired by Keynes's 'widow's cruse' analogy concerning capitalists earning what they spend. The instability problems, identified by Keynes, concerning business investment behaviour in the short period were recognised but, ultimately, the warranted growth rate, determined by the savings rate and the capital-output ratio, and the natural growth rate, determined by the population growth rate and the rate of productivity growth, were viewed as automatically equalised through distributional connections between savings and investment. This was seen by many as a remarkably powerful theory because it stepped away from the apparent theoretical nihilism of Harrod's non-equilibrium approach towards a theory that had a stable long run equilibrium state (Robinson 1956). But, for many economists, particularly in the US, the central problem was that the particular Classical approach chosen had no market price mechanism in operation.

Unsurprisingly, this was not the long run equilibrium growth theory that would take root in the mainstream of economics. Its Classical focus, combined with its Keynesian features, meant that there was little or no connection with Schumpeter's vision of economic growth as driven by entrepreneurship and innovation, honed by a competitive selection process. Notwithstanding the later work of Pasinetti (1993) the Cambridge model remained largely silent on the evolution of the economic system, although Kaldor (1985) did address evolutionary questions shortly before his death and he had previously introduced an endogenous 'technical progress function' into the Cambridge growth model giving it a limited evolutionary character.

As is well known, it was the self-equilibrating neoclassical growth theory of Robert Solow which began to command most attention because of its familiar neoclassical micro-foundations. But, elegant as it was, growth accounting suggested that it could not explain much of observed economic growth – there was a very large unexplained residual. Clearly, if the aforementioned economic historians were right, then this result was not surprising – all the factors that they highlighted would have to be contained in this overwhelmingly important residual. And it gave real force to Schumpeter's view that technological and organisational innovations were the engine of economic growth. Now, what might have been expected in such circumstances was the development of a new theory of economic growth where neoclassical features were retained, but in a *secondary* role, i.e., the kind of theory that Alfred Marshall had in mind. But this was not to be. Instead, once the 'capital controversy' in the 1960s and 1970s had run its course and the neoclassical economists at MIT had won its ideological war with the Cambridge School after losing almost all of the intellectual battles, ingenious attempts were made to enrich Solow's neoclassical growth model in a way that would reduce the unexplained residual.

In the 1980s, there grew up an 'endogenous growth theory' literature that incorporated factors such as education, R&D and increasing returns due to the low cost transferability of knowledge. The end result was a growth theory that was an extension of Solow's neoclassical theory but, as might be expected of a theory that remained in the timeless dimension of analytical equilibrium states, relatively little real progress could be made in disentangling and measuring the various causes of economic growth empirically. The theory remained so abstract and detached from actual historical experience that it could not provide a satisfactory basis for hypothesis testing. The data mainly employed in econometric modelling exercises have been cross country rather than historical. However, because the historical period in each country contains quite different evolutionary experiences, severe methodological difficulties arise, as discussed in Durlauf (2001) and Durlauf et al. (2008).

Any historian will tell you that the processes underlying economic growth are those of structural development and change. Economists who use neoclassical principles as the basis of their growth theories know this and most also realise that the historical data they are trying to understand are not reflective of such processes but, instead, measure the flows and accumulations of value that emanate from such processes. Thus, much of the evolutionary restlessness we observe at the microeconomic level is averaged out in macroeconomic data so that we often observe quite well-behaved trends. This tempts economists to argue that what is showing through is the optimizing behaviour of individuals and that this is the fundamental driver of economic growth. Thus, using a representative optimizing agent as the basic unit in theorising is regarded as an acceptable approximation.

Evolutionary economists have long rejected this perspective and argued that processes of competitive selection, even in the absence of optimising of the neoclassical kind, can result in economic growth provided that technological and organisational variety, from which heterogeneous innovations can be drawn, exists. The powerful mathematics of replicator dynamics has been employed to demonstrate how competitive selection operates. However, this theoretical approach also encounters difficulties in empirical application for two reasons:

> First, replicator dynamics can only reach an identifiable stationary state if variety is fixed. In the economic domain, variety is not fixed or even randomly generated, as is presumed in much of evolutionary biology. Instead, it is a product of the goal-directed efforts of people to innovate and create enterprises that yield profits. So, in the end, it is the generation of variety that is the primary source of economic growth. In history, both variety generation and competitive selection processes take place at the same time and affect each other. In other words, we are faced with the dynamics of a complex adaptive system with positive and/or negative feedbacks.
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> Second, it is often difficult to observe evolutionary economic behaviour in macroeconomic data because aggregation removes most of the dimensions of variety over which competitive selection can occur and, also, it averages out the effects of the entry and exit of firms and products. Thus, it is difficult to link aggregate economic growth with underlying variety generation and replicator dynamic processes, even if we can identify and model them at the microeconomic level. What is most likely to show up at the aggregate level is the *expansion* of variety which, in a complex adaptive system, is an outcome of a process of self-organisation (Foster 1997; Witt 1997). This process yields

a growing variety of organisational structures using a growing variety of processes to produce a growing variety of goods and services. All result in increases in aggregate value, once competitive selection has done its, largely invisible, work.

Given that we are dealing with complex adaptive systems, it is necessary to look at economic growth from a new perspective: the conventional way of dealing with a model is reversed: the primary dynamics are non-equilibrium ('disequilibrium' in conventional terms) and the secondary dynamics involve equilibration along non-equilibrium paths (referred to as homoeostasis in physics). A fundamental characteristic of such systems is that they exhibit a degree of structural irreversibility, rendering mathematical analysis that presumes reversibility invalid (see Foster and Wild 1999). Structural irreversibility is associated with 'order' in a complex structure, providing essential continuity over time. It is this order in structure that can be built upon in non-equilibrium modelling.

So the challenge is to devise an approach to understanding economic growth that recognises, explicitly, that we are dealing with complex adaptive systems that exhibit both self-organisation and competitive selection. This body of theory must be able to generate hypotheses that can be evaluated empirically to provide strongly supported explanations of behavioural phenomena, a capacity to engage in counterfactual analysis and/or prediction and results that are simple enough to guide policymaking. In the remainder of this paper, an approach that can achieve these goals will be discussed.

3 How Have Evolutionary Economists Dealt with Macroeconomics?

The birth of a coherent body of modern evolutionary economic thought was in Nelson and Winter's well known neo-Schumpeterian thesis on economic growth in 1982, which grew out of their critique of neoclassical growth theory in Nelson and Winter (1974). However, despite a vigorous and valid critique of neoclassical approaches to the theory of economic growth, their alternative approach was firmly microeconomic, built at the firm level and predominantly concerned with the supply side, using simulation techniques to aid theoretical understanding while eschewing econometric methods. This is an observation rather than a criticism because it was quite unclear at that time how economic analysis could be conducted at the macroeconomic level, building from explicit evolutionary hypotheses proposed at the microeconomic level. This being said, there were gaps in their coverage of relevant past literature: Metcalfe et al. (2006) point to the importance of the early work of Kuznets (1953) and Fabricant (1940) in explaining how the rise and fall of firms and industries, because of entrepreneurship, innovation and competitive pressures, can be connected with macroeconomic growth and fluctuation. Nelson and Winter (1982) did not cite these important contributions. However, perhaps even more significantly, Foster (1987) did not refer to them either, despite his central focus upon how macroeconomics can be built upon evolutionary economic foundations.

This disconnection has made it difficult to meet the challenge posed by Nelson and Winter, cited at the beginning of this article. Many neo-Schumpeterian evolutionary economists have continued to focus upon firms and industries on the supply-side and refrained from drawing macroeconomic conclusions from their analysis because of the aforementioned tendency for aggregation to wash out the interesting evolutionary dynamics. Nonetheless, there have been some important recent attempts to tackle this problem. Examples are: Verspagen (2002); Carlaw and Lipsey (2005); Dosi et al. (2006); Metcalfe et al. (2006); Saviotti and Pyka (2008) and Boehm (2008).[1] All of these contributors provide useful insights but it is striking that they do not use a common analytical framework or methodology. Some are simulation studies, some involve calibration, some employ econometrics and some employ mixtures of these. This has tended to place evolutionary macroeconomics at a competitive disadvantage in comparison with the relatively unified theoretical approach adopted by endogenous growth theorists. Indeed, by the late 1990s, growth economists, such as Aghion and Howitt (1998) had elaborated the endogenous growth model sufficiently to refer to it as a ‘Schumpeterian’ approach to economic growth. And it is true that the models developed have features that Schumpeter would have approved of but the connection with Schumpeter and the neo-Schumpeterian approach that grew up after Nelson and Winter (1982) is, at best, tenuous (Alcouffe and Kuhn 2004). Notably, these authors barely referred to the neo-Schumpeterian literature and one can only infer that it was deemed by them to be of very limited value in the quest to produce a macroeconomic theory of economic growth.

Evolutionary economics is very strong in providing analytical and empirical work concerning the innovation process and it is used, increasingly, in preference to mainstream economics by those trying to formulate innovation policy. However, the proposition that entrepreneurship and innovation yield aggregate productivity growth, although intuitively obvious, does not have a body of empirical evidence behind it that is closely connected with evolutionary economic analysis. Without such evidence, we do not know which policy instruments are most powerful, we have no clear idea of how long it will take for various innovation policies to impact on productivity growth and we are not sure what kinds of human capital it is best to support. This lack of a strong empirical connection between aggregate productivity growth and evolutionary economic processes makes it hard for evolutionary economists to compete with endogenous growth theorists, despite the fact that the latter do not offer much more in the way of empirical support for their key hypotheses using time series data. But, typically, when a scientific debate is outside the empirical domain, familiar modes of theorising tend to be preferred.

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[1]See Silverberg and Verspagen(1998) and (2005), pp. 220–224, for reviews of some earlier literature on evolutionary macroeconomic modeling of economic growth.

4 The Meso-Rule Foundations of Macroeconomics

As Saviotti and Pyka (2008) point out, when we are dealing with an economy or one of its components we are dealing with a dissipative structure. Such structures import free energy and materials to both maintain the system and, subject to boundary limits, expand its size and complexity. To maintain their integrity, these systems have to exhibit a degree of irreversibility and, therefore, their growth trajectory cannot be presumed to be a disequilibrium path to a final equilibrium state, in the sense that it is used in standard economics (Foster and Wild 1999). A stable equilibrium in such systems is a thermodynamic equilibrium which is a state of system death. However, along these non-equilibrium trajectories, complex systems do try to maintain a homoeostatic equilibrium state through the operation of various control mechanisms.

Economic systems, such as firms, differ from other natural dissipative systems in that they always produce output that is economically-valued. Thus, it is the net value of product outflows minus the value of inflows of energy (including human energy) and materials that is decisive for survival and growth. Consistent with the behaviour of any dissipative structure, as a firm grows and develops its managers will seek to maintain a homoeostatic balance between these flows through holding stocks, maintaining liquidity and/or accessing credit. However, we know that the basin of attraction within which such equilibrium can be maintained is limited. When it is exceeded, the firm faces bankruptcy or takeover. So, in the short period, variations in financial flows are important and, if too many firms slip out of their basins of attraction because of a negative aggregate shock, this can impact upon long period, non-equilibrium trajectories, leading to positive feedback and sustained underemployment of resources. This is, in essence, what Keynes was trying to explain. However, he did not set his analysis in an evolutionary framework although he did stress that long period decisions are dominated by the 'animal spirits' of business decision-makers (Foster 1989).

Evolutionary economists, Witt and Brenner (2008), following Hayek (1981), also argue that macroeconomic equilibrium should be understood in flow terms, not in terms of notional market equilibrium positions. So they accept that, in an evolutionary context, a negative demand shock can result in a short period under-fully employed equilibrium prevailing. However, they reject the notion that this is likely to be a very persistent state precisely because of the evolutionary adaptability of the economic system. The case that they are more interested in is where demand is so high that orders exceed the capacity of the productive system, inducing a short period flow disequilibrium that stimulates longer period investment behaviour. Witt and Brenner argue that the evolutionary nature of the economic system must mean that macroeconomic analysis must rely less upon standard market analysis than is the case in modern macroeconomics and, in so doing, provide a new connection between Keynes and the late writings of Hayek. However, this raises many new questions, as well as revisitations of old questions that arose in the time of Keynes. In particular, what are the long period evolutionary drivers of economic behaviour and how can we model such behaviour in the aggregate? Neither Keynes nor Hayek believed that econometrics could help because the long period was characterised by structural change and it was seen as being driven by socio-psychological behaviour outside the province of neoclassical economic theory.

The relative stability we observe in macroeconomic flow data over short periods is a result of the order that exists in the economic system which, in turn, results from inherent irreversibility. This is due to the fact that dissipative structures are connective networks that function by obeying rules. Correspondingly, evolutionary change involves changes in the rules that systems adopt. So it follows that evolutionary macroeconomics should focus upon rule systems and how they change. Thus, Dopfer et al. (2004) argue that, to do evolutionary macroeconomics, we need to build upon meso-rule foundations, not micro-foundations. They argue that the core of a complex economic system lies in its meso-rules which are expressed in a range of institutions such as customs, norms, routines, laws, constitutions, fashions, etc. These are adopted by populations and applied in a wide range of settings to generate economic value. The meso-rule system is viewed as hierarchical, ranging from relatively long lived core rules, which are applied across the whole economy, to short-lived rules that are specialised and contingent. So, for example, the meso-rules that are critical at the level of a particular industry are additional to the core, economy-wide rules upon which they rely. The same line of argument holds at the level of a firm. So what the evolutionary macroeconomist needs to discover are the high level meso-rules that are core to the hierarchical meso-set. These rules underpin others which, in turn, facilitate the production of diverse products in a variety of organisations. Thus, aggregate value, as measured in macroeconomic statistics, is directly connected with core meso-rules.

Of course, this idea is not entirely new since economists have, in the past, discussed the fact that institutions have an important role to play in economic growth. Going back to Kuznets, we find that he emphasised the key role that institutions play and that economic evolution is driven by changes in institutions. Undoubtedly, this was the influence of Wesley Mitchell at work, as was Kuznets' obsession with data and measurement. Nelson (2002) has also come to argue strongly that institutions play a pivotal role in economic evolution but, his perspective is more in relation to microeconomics than macroeconomics. The innovation that Dopfer et al. (2004) offer is a coherent perspective on how we can treat institutions theoretically and, with it, an explanation why meso-rules should be the core building block in economics, not just the vaguely specified 'market'.

However, we already know that institutions are hard to deal with empirically. Meso-rules emerge from individual imagination as micro-rules and become fixed in populations of individuals when they are deemed useful. Some get codified in legal rules but many do not. We can't quantify these rules in most cases, what we observe are the outcomes of the behaviour of individuals and groups using these rules in diverse applications. Furthermore, It is difficult to attribute an exact amount of value to a particular meso-rule because it tends to be applied as part of a meso-set but this may not be crucial at the macroeconomic level since, if we observe aggregate flows and stocks of value, then we know that there must exist a set of meso-rules that is effectively applied. This does not imply a static position because growth can occur with a given set of meso rules as long as there are available supplies of energy and knowledge to produce more output. In addition, incremental innovations and learning-by-doing can raise productivity. However, the radical changes that involve 'creative destruction' and the emergence of new processes and products to replace the old must involve changes in the set of adopted meso-rules. Thus, to understand economic evolution we must study the meso-rule shifts that have occurred.

We can never predict what micro-creativity will come up with, given a meso-rule, and we cannot predict what micro-rule will come to be adopted as a meso-rule by a population in the future. Typically, value grows along sigmoid diffusion curves as incremental innovation and learning-by-doing occurs, particularly at the level of a product or an industry. These are less in evidence at the firm level because meso-rule adoption involves much failure and discontinuity.[2] As has been noted, at the macroeconomic level, creative destruction tends to me masked but we do still observe significant longer period fluctuations in macroeconomic data that can be associated with core meso-rule shifts. Both the hypotheses of Schumpeter and Kondratiev, concerning the relation of long wave upswings to the adoption of new core technological and/or organisational meso-rules, are consistent with this view.

Associating macroeconomic fluctuations to changes in meso rules (or resistance to changes in meso rules) offers an alternative to the standard perspective. Thinking on business cycles tends to have been concentrated upon either the propagation of Frischian exogenous technological shocks or on Samuelson/Hicks style endogenously generated change due to nonlinearities and/or dynamical considerations. The meso-rule perspective views the arrival of new technological or organisational meso-rules as *systemic* rather than endogenous or exogenous.

It follows that, in order to understand the growth of an economy, we must know about its interconnected set of meso-rules and how this is shifting. This requires in depth historical study of institutions, technologies and organisational structures and, already, there is a rich literature in economic history concerned with this. For example, Landes (2003); North (2005) and Mokyr (2005), to name only a few, have made significant contributions. But their insights are largely disconnected from standard growth economics although there are some examples of endogenous growth research which tries to embrace the role of institutions, but with limited reference to the detailed historical record. For example, Rodrick et al. (2004) and Acemoglu et al. (2005) argue that certain kinds of institutions are vital for growth. Glaeser (2004) points out that this is likely to be a dynamic relationship with positive feedback – economic growth tends to promote better political and economic institutions. The problem with contributions is that they use the neoclassical growth model as the core starting point despite the fact that positive feedback is more appropriately dealt with in a systemic approach.

[2]Studies of innovation diffusion and associated logistic trajectories at the firm level deal, almost exclusively, with the successes, not the failures.

5 Energy: The Forgotten Dimension

In both endogenous and evolutionary approaches to understanding economic growth, we see little discussion of the role of energy. It is generally viewed as just another factor of production with strong complementarities with the use of capital goods (Ayres and Warr 2005). However, Schneider and Sagan (2005) argue that, if we view economic systems as dissipative structures, energetics become fundamentally important. Their thesis is that all dissipative structures always, directly or indirectly, seek to reduce the ‘free energy gradients’ that they face and, in so doing, become more complex structures with a capacity to access more free energy gradients. So, instead of energy throughput in a dissipative structure being a means to an end, they view it as an end in itself in an environment where free energy is available to capture. This thesis works quite well in biological contexts, bearing in mind that a species that throughputs more energy and grows more powerful is likely to be selected favourably. However, in the economic domain we do not consciously seek to maximize energy throughput. Yet we must acknowledge that such forces are at work, given our biological heritage. In applying our knowledge to create goods and services we throughput energy and the accumulation of knowledge gives us the capacity to access new free energy gradients to allow economic growth to occur (Metcalfe 2002). So a complete theory of economic growth must be a co-evolutionary one that involves the process of knowledge growth, the associated application of meso-rules and the growth of energy throughput (Raine, et al. 2006).

All human actions require energy throughput. The ‘animal spirits’ (‘will to action in preference to inaction’) highlighted by Keynes, involve a willingness to throughput energy even though it is unclear that any benefit will be obtained. So we find that, in the area of inventive, entrepreneurial and innovative behaviour, there is an intimate connection between economic actions, human and non-human energy throughput. Without the availability of a free energy gradient, there can be no economic action and, although economists tend to think of the latter as driven by tastes and preferences, the Schneider and Kay (1994) hypothesis that, in fact, economic action can be viewed as just another way that dissipative structures throughput energy to take advantage of free energy gradients, has to be considered seriously as part of the story of economic growth.

Because the economic growth process is primarily about the formation and application of knowledge structures in human minds (Metcalfe and Ramlogan 2005), the energetic side of the story has been underplayed, despite protestations from time to time (see, especially, Georgescu-Roegen 1971 and Boulding 1978). Instead, unacceptably strong assumptions have been made about the perfection of knowledge and the computational capacity of humans (Steedman 2004). Perhaps, this is because it is not easy to provide an analytical representation of the behaviour of a complex adaptive system, with limited knowledge and skills, trying to find free energy gradients in a complex environment. Although there have been many inspirational writers that have tried to follow this path, in neo-Austrian, neo-Schumpeterian, post-Keynesian, American institutionalist and ecological economics, a simple analytical framework still remains out of reach. Non-equilibrium complex adaptive systems cannot be adequately represented by systems of equations with equilibrium solutions, obtainable by mathematical deduction.

What Corning (2002) refers to as ‘thermoeconomic principles’, following Lotka (1922a, b), and echoed by Georgescu-Roegen (1971); Boulding (1978); Schneider and Kay (1994); and Buenstorf (2000), are seen as characterizing living systems. They seek to increase access to energy sources, and/or increase the efficiency of currently employed energy transformation processes. The development of technological and organizational structures represents investments in organized complexity in order to process more free energy and materials and, of course, meet more needs. Technological meso-rules determine the physical possibilities for energy transformation, while organizational meso-rules enable human energy and skills to be coordinated within the networks of economic systems. Within these meso-rule structures, useful information and useful energy flow and outputs are generated that enlarge scale and complexity. But as we have noted, such systems cannot grow without limit – both internal and external boundaries exist and, when these are approached, structural discontinuities occur (Dyke 1990; Tainter 1990).

Although the energy dimension of the growth process has been virtually ignored in endogenous growth theory, it has not gone unnoticed in energy economics and ecological economics. Both Jorgensen (2005) and Ayres (2001) have provided evidence that most of the ‘Solow residual’ can be accounted for by including useful energy flow in the production function as a factor and acknowledging the rising impact of ICTs (by distinguishing the ICT from the non-ICT capital stock in Jorgensen’s case). This work echoes that done in earlier years by Jorgensen (1986) and Berndt (1991). Processes of diffusional growth of this kind are dominated by learning by doing, incremental innovation and competitive selection mechanisms that favour certain products and certain processes. These processes are, necessarily, associated with increase in the quantity and quality of useful energy or in increased energy efficiency. In the case of ICTs, it has been the availability of high quality, portable and cheap energy in the form of electricity, which has been pivotal (Ayres et al. 2007).

However, if we are seeking to explore the validity of the hypothesis that energy throughput is a fundamental co-evolutionary dimension of the growth process, these studies, although indicative of the importance of energy, adopt a production function methodology that treats energy only as an input. The implications of energy and knowledge bi-causality have to be considered from a more systemic perspective. Energy flow is mediated by the design and use of extractive, transformational, distributional and utilisation systems. All these involve the accumulation and use of knowledge which, in turn, requires the use of human and non-human energy. The technological and organisational meso-rules embodied in these knowledge-energy systems both facilitate and constrain economic growth in a fundamental way. Once such a system is in place, it is difficult to change without a radical shift in core meso-rules. Currently, this can be seen clearly in the case of attempts to shift from coal-fired power generation to non-carbon emitting systems. Historically, core meso-rule shifts in the area of energy and associated natural resources have sometimes been traumatic. Diamond (2005) provides historical examples where such difficulties have pushed previously successful societies into 'dark ages' and even eliminated some.

6 An Evolutionary Macroeconomic Framework: Keynes Meets Schumpeter

We are all familiar with the circular flow of income and expenditure relation in macroeconomics. Schumpeter understood it well and was excited by the manner in which Leon Walras tried to conceptualise a general equilibrium in such a flow system although he was never able to reconcile this with his own conceptualisation of system where flows of income/expenditure and credit facilitate structural change in the economic system. Keynes used the circular flow as the bedrock of his theory of effective demand. As noted, Saviotti and Pyka (2008) and Witt and Brenner (2008) have stressed that the neoclassical representation of equilibrium is untenable in a complex, evolving system, reasserting the centrality of the circular flow perspective.

In his macroeconomics, Keynes disaggregated income/expenditure flows only minimally. To make his point in a closed economy, it was enough to split expenditure into that of consumers, investors and government. They were chosen because their aggregate behaviour was presumed to differ in important ways. The key problem was that investment in capital involves a commitment to a stock which displays a high degree of irreversibility. Therefore, investors become nervous and capricious in their behaviour, anxiously looking at the actions of other investors when deciding what to do. Collective decisions to cut back investment because of anticipated slackening of consumer demand generate a feedback, whereby anticipations are vindicated. Thus, dynamics become endogenous and this encouraged the development of multiplier/accelerator models of the business cycle by Samuelson (1939) and Hicks (1950). Keynes did not attempt to formalise such a process since he clearly did not believe that an accelerator coefficient would be stable across history and he was largely vindicated by the failure of econometric research concerning the business cycle after his death. Indeed, the accelerator made few people happy. For the equilibrium theorist, it was an atheoretical construction and for close followers of Keynes is was a matter of misplaced concreteness.

The problem in extending Keynes's approach is that he focussed primarily upon economic breakdown and the introduction of a stabilising government to avert depressions. Necessarily, Keynes's circular flow model is fixed structurally, in the sense that the marginal propensity to consume is related to income in a mathematical manner, otherwise the multiplier could not be discussed as a stable magnitude. Such an abstraction does not deal with underlying economic complexity and the manner in which this complexity changes but, rather, the income-expenditure flows that facilitate the maintenance and development of that complexity. Keynes was dealing, not with the co-ordinating role of the market, but, more generally, of money flows. Thus, his model reflects the organisation of the economic system as one of monetary exchange and contracting. It is limited in its scope because of the way that business investment is dealt with. The effects of fluctuations in business confidence on the circular flow are captured but there is no evolutionary dimension to the model which can help us address, for example, the emergence of underlying structural unemployment.

However, from an evolutionary perspective, it is relatively straightforward to disaggregate investment expenditure in a manner which reflects the dynamics of a Schumpeterian, evolving economy:

1. *Strategic investment*, which involves expenditure on items which help defend market share, such as marketing and sales promotion, product differentiation and the erection of entry barriers and a range of other rent-seeking activities.
2. *Investment in expenditure which is necessary to keep production going*. This includes the provision of stocks of inventories throughout the production process and maintenance and repair expenditures.
3. *Investment in cost-cutting methods*, such as organisational improvement and labour saving technologies.
4. *Entrepreneurial investment* leading to the adoption of new inventions and innovations that result in new products and new production techniques.

Schumpeter addressed all four of these investment categories, indicating that the most important for economic evolution is (4). Category (3) was also regarded as involving innovation, but only of the incremental, Marshallian, type. Keynes, in effect, focussed upon (2) in his model – buffer stocks are critical to the working of the multiplier process. Investment in the capacity to seek rents in (1) was for Keynes, as it was for Marshall, a matter of ethics. He also accepted the importance of Category (3), in the sense that it involves 'economising' investment behaviour which is sensitive to the cost of capital. Category (4) was designated as entirely socio-psychological and subject to the ebb and flow of confidence. Keynes appreciated fully that Categories (3) and (4) are fundamental in determining the position of short period macroeconomic flow balance but kept them quasi-exogenous on the ground that economists could not understand them using the analytical tools at their disposal.

At any level of aggregation in the economy, the flow of investment expenditure will contain all four components. However, an emphasis on each has different implications for economic evolution. Let us examine these in turn:

Category (1) is, in essence, political and a strong emphasis on this type of investment will be at the expense of other categories, particularly Category (4). At the level of the economy, it leads to the predominance of economic structures which are organised in line with power structures. A shift towards category (1) investment at any level may well increase employment in an economy facing economic difficulties, as was the case in the 1930s in Germany. The political imposition of strong hierarchical order, in societies which were previously in disorder, can yield employment payoffs. Spill-over into Category (2) and (3) investment can lead to further employment gains and, for a while, productivity gains. However, since Category (4) investment in the private sector is the fountain of economic evolution, such systems tend towards inertia, productivity decline and ultimate collapse. Such societies are not characterised by unemployment but, rather, by an ever worsening distribution of income and wealth. In societies emphasising Category (1) investment, we do, indeed, have Hayek's 'road to serfdom'.

Category (2) investment is necessary to keep structures going. However, over emphasis on (2) at the expense of (3) and (4) results in inertia and ever escalating costs because of the presence of entropy processes and analogous tendencies towards disorder in all structures. There is a rising tendency for labour to be absorbed for the purposes of maintaining an increasingly inert system. The Soviet system before its demise tended to emphasise Category (2) investment patterns with little Category (3) 'economising' or Category (4) enterprise.

Category (3) investment often occurs when capital equipment has depreciated to the point where it needs to be replaced. Cost-cutting strategies, which normally involve capital/labour substitutions, are adopted. When the task to be performed is relatively well-defined, it is possible to apply conventional investment appraisal techniques. Investment in organisational rearrangement can also occur. The outcome of this type of investment is generally labour saving. In standard economics this is the primary way of looking at investment. Over-emphasis on this type of investment, at the expense of Category (4) investment, can lead to rising unemployment. This is simply because insufficient new jobs, and associated training programmes, are generated in emergent industries. However, the linkage between Category (3) and (4) is a complex one – Joseph Schumpeter suggested that Category (3) investment can sometimes lead to the unintended consequence that a firm enters a new, category (4) niche. For example, the purchase of a replacement machine tool with much more accurate tolerances may lead to the possibility of producing novel, high precision products. Indeed, there is plenty of evidence that many firms that do not undertake innovation in any explicit manner survive because of the technological change embodied in replacement plant and equipment.

Category (4) investment is difficult because it creates novelty and opportunity in the future and the benefits are not easily quantified *ex ante*. Category (3) can involve profit maximisation but (4) has to be limited to profit seeking. And there is the risk that profits will be expropriated by someone else in the uncertainty that prevails. Nonetheless, most managers know that, without entrepreneurial activity of this type, or a capacity to mimic the successful innovations of other firms, the organisation will struggle to survive in the longer term. Entrepreneurial firms which have been successful in Category (4) investment, or in hijacking the innovations of others, may begin to switch to Category (1) defensive investment if their market niche is limited and, thus, the Schumpeterian circle of creative destruction is closed.

So how can we conceptualise these distinctions within a macroeconomic model?

First of all, the distinction between 'investment' and 'consumption' becomes blurred. Our four categories apply equally to consumption that flows from consumer durables and other personal assets. Also, the consumption of services and food for immediate consumption can be viewed as, to a large degree, part of (2). In conventional economics the focus has been on consumption because of its natural connection with individual utility theory. However, an investment focus seems more relevant when constructing an evolutionary macroeconomic perspective on economic growth.

We have argued that economic systems are dissipative structures with certain characteristics and that the best way to represent them is in terms of value flows and that this applies as much at the macroeconomic level as, for example, at the level of the firm. So we can begin with the following simple identity:

$$Y_t = Y_{t-1} + Z_t - W_t \tag{1}$$

Or, rearranging:

$$Y_t - Y_{t-1} = Z_t - W_t \tag{2}$$

Where ***Y*** is the output flow of value emanating from a system, ***W*** is the flow loss due to wear and tear, breakdowns, etc., and ***Z*** is the output value flow increase due to investments in novel products and processes. Clearly, if ***Z*** exceeds ***W*** then there is growth and *vica versa*. So only part of ***Z*** will lead to new value creation from the production of greater output of existing products or the output of new products.[3] Time delays in the impact of new investments on output will mean that ***Z*** effects will emanate from new investment expenditure in earlier periods. Thus, there are complicated dynamics involved that have tended to show up in past attempts to model, econometrically, investment expenditure and its macroeconomic impacts. Complex systems theory predicts that, if meso-rules are fixed and, therefore, Category (4) investment does not occur, growth will eventually run out as ***Z*** becomes, increasingly, committed to dealing with ***W*.** Even though this cannot be accurately measured, particularly at the aggregate level, it will be reflected in shrinking gross surpluses and a consequent slowdown in the growth of ***Y***. In other words, ***Y*** is likely to follow a diffusion curve of the logistic, Gompertz, or some other sigmoid form, for a given meso-set. At the macroeconomic level, an example would be a Kondratiev upswing following the establishment of a new core meso rule (or set of rules).

So, when we are examining the circular flow of income and expenditure, we need to know about core meso-rules and how these are adapting since this will influence the size of investment in each of our four categories and current and future economic growth. In Keynesian analysis, the only objective is to ensure that there is sufficient investment of any kind (as in Keynes' famous example of digging holes and filling them in again). To understand growth, we need to disaggregate investment and examine the determinants of each. Provided that innovative new Category (4) investments occur, either directly, or as an unintended consequence of Category (3) investments, then the system need not end up in a structurally unstable stationary

[3]This is often thought of in terms of 'replacement' and 'net' components of investment expenditure but, as Scott (1989) stressed, this can be misleading because 'replacement' often involves the simultaneous upgrading of productive structure and output.

state. Growth will occur when new meso-rules replace old ones and there is associated replacement of new productive processes for old (cost reductions) and new goods and services for old (revenue increases). Unproductive firms and industries disappear and new ones arise.

The average position of the whole economy is determined by the distribution of industries that are at different points on diffusion curves or in downward phases of decline. Each industry has a different productivity growth rate, as Solomon Fabricant so clearly pointed out over half a century ago (see Metcalfe et al. 2006). Thus, the productivity growth of the whole economy depends on the weighted average of productivity growth in different industries. In the words of Metcalfe (2002), economic growth depends on the 'restlessness of capitalism'. But this restlessness is not confined to the competitive selection process. It involves restless minds, constantly seeking to invent, to innovate and to connect with other minds in productive organisations in the quest for profits. The mainspring of economic growth lies in these self-organisational tendencies (Foster 2000). Therefore, the identification and measurement of these tendencies and their impacts have to be central in any empirical methodology that we use.

7 Towards a New Empirical Methodology

Since economic growth depends, ultimately, upon the set of meso-rules that exists and how this set changes, macroeconomic modelling of growth has to involve the identification of meso- rules and a capability to connect them with appropriate macroeconomic time series data that, in turn, reflect what is happening to our four categories of investment. In doing this, we must be careful not to adopt the conventional methodology of removing non-stationarity from time series data because this provides important information concerning the process of economic growth over historical time. Also, we cannot rely on average representations of non-average processes, and we have to dig deeper than is the case in Keynesian income/expenditure analysis to discover the variables that relate directly to meso- rules and, therefore, economic evolution. So, for example, if we are dealing with a recessionary down turn in the US economy because of a crisis in 'sub-prime' lending that had boosted Category (1) investment, we need to discover the meso rule set that was the source of the problem, connect it with the relevant macroeconomic data, and then to the behaviour of the economic agents directly involved, to understand why the crisis and downturn came about.

When using time series data in economics, the picture is always incomplete. So we have to be pragmatic and try to link economic analysis to the limited data we have at our disposal. Fortunately, we now have very well-developed techniques to assess how the statistical series that we have are related to each other. These relationships tell us a great deal about the structure of the economic system. However, because data measure mainly value streams and stocks of value, they tell us little about the actual processes going on within systems. However, as noted, we know that these value streams were generated by such processes which, in turn, were mediated by meso-rules. We can never capture the intricate complexity of economic processes in a model but we can link important meso-rules with aggregated value streams.

Foster and Potts (2009) have offered a methodology that makes this link and includes the following steps:

- Detailed historical investigations over the selected time period to identify key meso-rules that are relevant to understanding the growth process. Any tendency for these rules to become more or less pervasive must also be assessed.
- A detailed statistical investigation of the associations between all the available data series over the specified time period that measure flows and stocks in the system in question.
- A search for connections between observed statistical relationships and the pre-identified meso-rules.
- A further inductive search for meso-rules that can be linked with other discovered statistical associations.
- The elimination of statistical associations without a meso-rule counterpart.
- The construction of artificial data, such as a dummy variable series, to reflect key meso-rules, discovered in historical investigations, that are clearly important but do not have statistical counterparts.
- Econometric estimation of a parsimonious growth model (using both conventional and Bayesian econometric methods) in which all variables and/or associations between variables are linked with identified meso-rules.
- The construction of an agent-based model in which 'meso-agents' obey the identified meso- rules, but with varying parametric strength to reflect micro-diversity and to allow for associated success and failure, with the restriction that the population average must equal the estimated macro-parameter.
- Calibration of the resultant simulations on actual macroeconomic data within and beyond the sample period.[4] Since, in the main, econometric modelling must be restricted to periods when there are no large structural discontinuities in the data, the strongest calibration test is to track the data through a discontinuity beyond the sample estimation period. This is a demanding test and is based upon the systemic view that such discontinuities are a product of rules already present in periods of apparently steady growth, in the absence of obvious exogenous shocks.

[4]As we have noted, evolutionary economic trajectories that are non-equilibrium in nature and rarely have analytical solutions. Therefore, their properties have to be discovered through simulation and calibration. Simulation models are generally, 'bottom up,' starting at the level of microeconomic behaviour and, frequently these days, agent based simulation techniques are employed. However, there are well known problems with the simulation approach, particularly when calibration is employed in the presence of free parameters (Werker and Brenner 2004). This suggests that we need more than an inductive approach to discovery, but without recourse to timeless, abstract theorising in the standard manner. This is the goal here, as it has been in some careful 'history friendly' firm level studies (see, for example, Malerba et al. 2001).

This methodology concurs, to some extent, with the ‘triangulation’ methodology proposed by Downward and Mearman (2007). It also connects with the methodology suggested by Durlauf et al. (2005) who advocate an ‘eclectic’ approach, involving both prior historical case studies and the eventual calibration of estimated parameters with those suggested by theoretical models. They point out that Bayesian econometrics is particularly useful in this kind of methodology. Historical studies that identify meso-rules provide ‘grounded’ theory from which good priors can be drawn for this kind of estimation (see Bewley and Griffiths 2001). Importantly, the restriction of the parameter space that simulated agents can enter, based upon the limited set of meso-rules identified by historical research, and the application of only selected estimated parameters, based upon the statistical investigation of the relevant time series data, provide a robust test bed for evolutionary hypotheses. The standard neoclassical macroeconomist’s criticism of the agent-based simulation/calibration methodology – that there are too many free parameters and too many degrees of freedom – does not hold if this new methodology is applied appropriately.

8 Concluding Remarks

Endogenous growth theory has been popular in recent years but problems have arisen with regard to the empirical testing of hypotheses drawn from it. First, there has been criticism of attempts to operationalise endogenous growth theory empirically using cross-country (mainly, Summers and Heston database) data. Second, attempts to graft ‘Schumpeterian’ features on to what is, ostensibly, a non-Schumpeterian analytical framework has meant that it has been very difficult to operationalise the resultant models empirically because of the very strong assumptions made. For example, Francois and Lloyd-Ellis (2003) offer no empirical work at all and Iyigun (2006) provides only simulation results. So policy guidance has been limited, beyond general pleas for more education expenditure and R&D support (see Aghion and Howitt 2005). Thus, endogenous growth theorists have offered some analytical results and some simulations and calibrations but nothing very concrete in terms of an empirically supported assessment of the relative contribution of different drivers of growth which could be used to base country specific policies upon.

It has been argued here that a coherent evolutionary macroeconomic approach to economic growth is possible, both analytically and empirically. By connecting macroeconomic data with discovered meso-rules, rather than the behaviour of microeconomic agents, it is possible to have a macroeconomics that builds upon Keynesian and Schumpeterian, rather than neoclassical, principles. The quoted challenge that Nelson and Winter posed in 1982 must be met if evolutionary economics is to gain the attention in the community of economists that it deserves. At the present time, macroeconomics is in decline as a sub-discipline and the result has been poor macroeconomic policies often with only one instrument – the interest rate – being applied to meet many competing targets. Even with this single instrument, understanding of its impact has been limited.

Conventional macroeconomists have failed to offer convincing enough evidence concerning the key priorities for the long term that might receive bi-partisan support. It is intuitively obvious that entrepreneurship and innovation enhances productivity growth but which of the many policy possibilities to stimulate innovation is the most effective in macroeconomic terms? We do not know because conventional macroeconomic analysis has not been devised to answer such questions. But it is also true that evolutionary economics hasn't either, having been largely microeconomic and supply-side focussed. Clearly it is not an easy task to do macroeconomics when it is acknowledged that we are dealing with complex adaptive systems and subsystems that are structurally changing. However, the argument made here is that, once we acknowledge that systems are, in fact, networks of meso-rules and that these networks have structural coherence that can be modelled analytically and empirically in historical time, a new kind of macroeconomics becomes possible.

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