A micro-meso-macro perspective on the metholdology of evolutionary economics: integrating history, simulation and econometrics

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Introduction

Applied economics has long been dominated by multiple regression techniques. In this regard, econometrics has tended to have a narrower focus than, for example, psychometrics in psychology. Over the last two decades, the simulation and calibration approach to modeling has become more popular as an alternative to traditional econometric strategies. However, in contrast to the well-developed methodologies that now exist in econometrics, simulation/calibration remains exploratory and provisional, both as an explanatory and as a predictive modelling technique although clear progress has recently been made in this regard (see Brenner and Werker (2006)). In this paper, we suggest an approach that can usefully integrate both of these modelling strategies into a coherent evolutionary economic methodology.

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1. Introduction

Applied economics has long been dominated by multiple regression techniques. In this regard, econometrics has tended to have a narrower focus than, for example, psychometrics in psychology. Over the last two decades, the simulation and calibration approach to modeling has become more popular as an alternative to traditional econometric strategies. However, in contrast to the well-developed methodologies that now exist in econometrics, simulation/calibration remains exploratory and provisional, both as an explanatory and as a predictive modelling technique although clear progress has recently been made in this regard (see Brenner and Werker (2006)). In this paper, we suggest an approach that can usefully integrate both of these modelling strategies into a coherent evolutionary economic methodology.

In mainstream economics, simulation/calibration came to prominence in the 1980s in the real business cycle (RBC) literature. An RBC model cannot be estimated econometrically because of the very strong and unrealistic assumptions that are made (Altug (1989)). Following Kydland and Prescott (1982, 1996), simulation/calibration became the preferred modelling approach. However, the 'calibration' usually attempted is minimalist: the hypothesis that is supposed to be 'tested' is that the highly abstract forces reflected in such a model lie at the core of what is going on in real economies. It is argued that, if the variances of simulated and actual data are found to match in some proximate sense, this constitutes supportive evidence that the RBC model does, indeed, lurk deep within the economic processes that we observe through the lens of economic time series data. Not surprisingly, this methodology has been heavily criticized, both within and beyond the new classical school of thought (see, for example, Hoover (1995)).

[1] We would like to thank those who commented on an earlier draft of this article at the International J.A. Schumpeter Society Conference in Sophia-Antipolis, Nice, France, June 21-24, 2006.

RBC theory is the outcome of pleas constantly made by neoclassical economists for a new macroeconomics that has clearly connected 'micro-foundations.' This has posed a major difficulty for mainstream economists because it is virtually impossible to aggregate from micro-theoretical foundations to the macroeconomic level in any analytically tractable way without very strong and unrealistic assumptions. Indeed, insistence that macroeconomics must have such micro-foundations has all but destroyed macroeconomics as a viable sub-discipline of economics. So most of the macroeconomics that we now find in influential academic journals is just 'representative agent' microeconomics cast within a general equilibrium framework.[2] All that RBC theorists have done is to generate 'dynamic' models in which the inter-temporal reallocations of an all seeing and all knowing representative agent in the face of exogenous shocks result in 'macroeconomic' phenomena, such as business cycles.[3]

Applied macroeconomists have, in general, been singularly unimpressed with RBC simulation/calibration, preferring to apply econometric modeling approaches that are built upon statistical, rather than theoretical, foundations. Vector error (or equilibrium) correction (VEC) representations of time series data are overlaid by 'long run equilibrium' restrictions suggested by economic theory, which can come from a variety of sources and traditions. Whereas RBC theorists are primarily concerned with explanation, VEC modelers are more interested in forecasting variables out of sample. Tests of co-integration between time series are conducted to ensure that a valid VEC model can be constructed. Misleadingly, these are often viewed as tests of hypotheses derived from 'long-run equilibrium' theory. As might be expected, some of the most strident attacks on this statistically driven methodology have come from new classical economists and, of course, their RBC offspring. So mainstream macroeconomics contains an almost unbridgeable gap between theorists using simulation/calibration in a stochastic neoclassical world trying to *explain* macroeconomic phenomena and applied economists trying to *predict* such phenomena using statistical time

[2] Paradoxically, the kind of microeconomic theory that is used by macroeconomists has long been abandoned by most microeconomists as they have recast their analysis in terms of strategic game theory.

[3] The RBC approach to macroeconomics represents an extreme position along a spectrum of opinion concerning the degree to which macroeconomics should have 'micro-foundations'. At the opposite extreme, lies the position of John Maynard Keynes where it is envisioned that the macroeconomic level of an economic system has features that are not reducible to the microeconomic level.

series analysis, converted into econometrics by the imposition of theoretical restrictions.[4] When theory and empirics are so separated, virtually any proposition can be supported while policy-makers, confronted with ambiguous economic advice, find it difficult to connect instruments and targets.

In evolutionary economics, there has never been a strong tradition of using econometrics, beyond the investigation of special questions such as the parametric structure of innovation diffusion curves. The reason for this is clear: when significant structural change is present, conventional econometric methods are mostly unsuitable for empirical research because the classical assumptions required for valid econometric analysis are breached. It is also the case that evolutionary economists have not been very interested in macroeconomics since their non-neoclassical perspective on microeconomics offers no coherent way that microeconomics and macroeconomics can be linked. The notion that the macro-economy can be looked on as a separate system, whereby the ‘whole is greater than the sum of the parts’ is a perspective that is most strongly associated with the Post-Keynesian School of economic thought.

Much of evolutionary economics has been focused upon the behaviour of the firm and the industries that they populate. In this context, simulation/calibration has played a central role in exploring the outcomes of economic process within firms, between firms and between firms and consumers. Unlike mainstream microeconomics, game theoretics have not been dominant because evolutionary economists think in terms of the interactions of many heterogeneous agents in situations of change, not two or three in well defined static situations where pay-offs can be assessed. Instead, agent-based modelling (ABM) has been an important analytical approach in modern evolutionary economics ever since the seminal contribution of Nelson and Winter (1982). Perhaps the best recent example of research in this tradition is that of Malerba et al (2001) who offer a ‘history friendly’ methodology. The goal of this methodology is to conduct ABM in contexts that, as accurately as possible, reflect the historical and institutional conditions that existed in the period of time under consideration. Thus, simulation/calibration is conducted in precisely the opposite context to RBC – it embraces history rather than eliminating it.

[4] Interestingly, Nobel Prizes have been awarded to both camps in successive years: Kyndland and Prescott (in 2005) in the former and Engle and Granger (in 2004) in the latter.

However, as Werker and Brenner (2004) point out, the ABM approach faces a fundamental difficulty: it is possible to generate a wide range of ABM models that can calibrate on a given set of time series data since there are no formal restrictions that can be placed on all of the chosen parameters. This led them to argue for a critical realist methodology that, somewhat like the history friendly approach,[5] involves considerable historical and case study investigation prior to simulation. This results in models that are quite specific to the firm or industry in question. The stylized representations of complicated historical processes that are obtained are then used for counterfactual experiments, but it is uncommon for researchers in this tradition to draw out general theoretical principles from these simulation exercises that might, for example, provide a more developed analytical basis for more aggregate evolutionary economics in the style of, say, Metcalfe, Foster and Ramlogan (2006).

History friendly modeling is, essentially, about the existence and adoption of rules in economic behaviour. In this sense, it belongs to what Nelson and Winter (1982) referred to as "appreciative theory" concerning the pivotal rules that are observed to operate in economic organizations, particularly firms. But, as is well known, few mainstream economists have embraced Nelson and Winter's approach to economic growth because it does not start in "formal theory", i.e., theory that can be generalized across firms and industries in a way that can provide analytical foundations for the macroeconomics of economic growth. Endogenous growth theory, which was cleverly constructed from neoclassical economic foundations to cover some aspects of the Schumpeterian story (Aghion and Howitt (1998)), became the preferred approach. And, very oddly, the empirics favoured by endogenous growth economists has not involved much in the way of time series econometrics but, rather, cross-country econometrics over defined time periods. In recent years, this empirical approach has come to be criticized widely (Durlauf (2001)) .

Another reason why the Nelson and Winter (1982) approach did not become popular was that it offers a rather incomplete representation of the economy: it focuses mainly upon replicator dynamics operating on the supply side of the economy. The process of 'variety generation' and the demand side receive far too little attention (Foster and Potts (2006)). Furthermore, although the importance of routines in firms is emphasized, too little attention is given to the generic rules that facilitate coordination in the wider economy (Dopfer and Potts (2007)). For

[5] But see Brenner and Werker (2006) for a more fine-grained comparison of their approach to that of Malerba et al (2001).

Nelson and Winter (1982), routines were like genes – subject to competitive selection, depending upon the success or failure of productive process and products (phenotype-like) that they give rise to. It was not until the 1990s, that a literature began to develop in evolutionary economics where it was argued that, because the process of variety generation is often markedly non-random, this implies that the generic rules involved are of a quite different character to those envisaged in classical genetics. Among others, Foster (1997) and Witt (1997) argued for an explicit self-organisational approach to evolutionary economics. Then, following Kirman (1983), Potts (2000) argued for a 'network and connections' perspective on economic evolution using graph theory as an analytical representation of connective arrangements. Dopfer, Foster and Potts (2004) went on to exposit a 'micro-meso-macro' approach in which rule systems (and how they adapt) are the building blocks in complex economic systems (see also Dopfer and Potts (2004, 2007)). A key implication of this approach is that the variety generation process and associated learning and innovative processes are of prior importance over competitive selection mechanisms in understanding the process of economic evolution, echoing older and less formal institutionalist and neo-Austrian perspectives, but within a modern systems perspective.

The purpose of this article is to offer an outline of a methodology that can connect macroeconomics with microeconomics theory via the 'micro-meso-macro' analytical framework. It is intended to be an integrated methodology that involves a combination of econometrics, agent based simulation and in depth historical and/or case study.

2. Micro-Meso-Macro

The micro-meso-macro framework places generic rules at the centre of economic analysis. The economic system is viewed as being made of cognitive, behavioural, socio-cultural, organizational, technical and institutional rules. The analytic concept of a meso unit is a rule and its population of carriers and, in this sense, the economy is made of meso units. Microeconomic analysis is the study of the individual carriers of the rule and their local operations, and macroeconomic analysis is the study of the effects of coordination and change in the meso structure of the whole economy. From this perspective, economic evolution involves the origination, adoption and retention of a novel meso rule in the micro and macro structure of the economy. [6]

[6] Dopfer and Potts (2007) outline this analytical framework from ontological first principles.

Economic activity relies upon the existence of embedded generic rules with stable carrier populations (a generic rule and its carrier population is called a meso unit). These have been referred to variously in the past as institutions, norms, understandings, laws, technologies, etc. They are rules that are held by more than one person and are 'fourth order complex' in the sense that an individual believes that another upholds the rule and visa versa (see Foster (2005) and Klochko and Ordeshook (2006)). If this communality of understanding exists at the meso level in a carrier population, then economic activity can occur and value can be generated. The meso contains the underlying rule-processes that constitute the generic basis of economic operations. The meso domain of analysis, then, is the proper foundation for both evolutionary microeconomic and evolutionary macroeconomic analysis.[7]

The evolutionary micro domain contains carriers engaged in a myriad of activities (or operations) facilitated by meso rules resulting in a heterogeneous range of processes and products that have economic value that can be aggregated up to a defined macroeconomic level as the aggregate of operational value from a given set of meso rules. Some generic rules have long lives and operate at the core of the economic structures, such as the rules of markets, property rights, hierarchy or other forms of organization. Others are short lived, coming and going in fads and fashions, such as the flared-trousers rule, or the nationalization of coal mines rule. At a point in time, the economic activity of an economy is determined by its generic structure of meso rules, some of which are deep and stable, others of which are shallow and passing. Economic evolution is a process that is associated with change in that generic structure. This is abstractly conceived as a three-phase rule-trajectory consisting of: (1) the origination of the novel rule as an innovation, (2) the adoption of that rule into a population of micro agents to form a population, and (3) the ongoing retention and use of the meso rule. New meso populations come into being when an idiosyncratic rule becomes the basis of an innovation and is adopted by other carriers because its application yields significant economic value.[8] Equally, generic rules can also die out when their applications cease to be of value and their meso populations diminish.

[7] Note that this is in contrast to RBC models that seek micro, not meso, foundations for macro.

[8] A patent is valuable if other carriers can use it profitably. So what is a technological rule is a saleable commodity rather than a meso rule. The meso rule in operation in such cases is the one that make patents possible in the mutual observation of patent (property) rights. However, such commodities can become meso rules if it becomes understood that a rule will be used generally, i.e., they will acquire significant public good characteristics. Microsoft Windows is a good example.

The rule perspective on economic structures and the productive processes that they enact suggests that it is unhelpful to summarise such structures in terms of the flow of inputs and outputs on a production function. Such structures, instead, are networks of components in which connections, which can be technological or organisational, are limited in number. Some connections are hard-wired and generic while others are relatively impermanent and peripheral. The operation of rules yields ‘work’ both in the traditional thermodynamic sense (technological rules) and in the organizational effectiveness sense (social rules). The product of work is economic value that depends upon demand. In turn, demand relies upon connections existing between products and preferences (Earl and Potts (2004)). At the micro level, these are observed in market and contractual connections. It is because organizational connections are so important both within and between economic entities, such as producers and consumers, that knowledge is so important (Loasby (2005)). Every marketing manager knows that information must be provided in order to establish product knowledge amongst consumers, and every production manager knows that shared knowledge is essential to make an organization function. And every entrepreneur knows that a viable business must make these connections. The micro-meso framework seeks to identify and analyze these connections as generic rules.

Economic structures, like all dissipative structures, must be open to absorb energy (or exergy). But they must also be open to absorb information both to develop structure and to transform inputs into products that yield income (or, in the case of consumers, utility). It is the capacities of humans to seek out knowledge that can, in turn, exploit energy in creative ways, that differentiates complex economic systems from other kinds of complex systems. Stable meso populations of generic rules are fundamental in such systems since they provide the essential order upon which complexity (or variety) can grow. It follows that the most coherent feature that we observe in a healthy economic structure is that its order is, to a significant extent, irreversible across a wide range of environmental conditions.[9] And, equally, the periphery of such systems can be characterized by a bewildering amount of variety and change. A meso unit, therefore, consists of a rule with a population of adopters (or carriers) that may vary from stable and homogeneous to changing and heterogeneous.

[9] In ecology, this is referred to as ‘resilience’.

Now, in providing an analytical representation of such an economic structure and its process and product characteristics, it is a mistake to think of it in terms of its distance from an idealized equilibrium flow of costs and revenues. Such idealized flows are value measures that do not exist in reality and, as such, they lack any connection with the distinguishing features of the incompletely networked productive structures that actually exist - always changing yet, in crucial respects, unchanging. All that is offered in the conventional account are hypothetical outcomes when the system is deemed to be in a hypothetical equilibrium position. And this is the way that most economic modelling begins – firmly in the timeless domain. Addressing reality then involves appeals that some markets are incomplete (some elements are unconnected), some knowledge is asymmetric (connectivity varies between sub-sets of elements) or that the system is in disequilibrium (it is temporarily disconnected). But, in reality, economic systems are never in the chosen hypothetical equilibrium state and never could be because one or more of the assumptions made does not hold in reality.

The core of this hypothetical approach lies in individual constrained optimization. Behaviour is viewed in terms of income constraints and choices between substitutes. Now, although it is undoubtedly the case that such behaviour is evident in reality, it is not a good beginning in trying to understand the behaviour of rule based dissipative structures such as firms and economies. Indeed, most of the assumptions made are about unrealistically strong and complete rules, such as the total connectedness over all space and time in the notion of 'perfect knowledge' (Potts (2000)). In contrast, the micro-meso-macro approach starts with the proposition that the rule systems that connect elements in an economic system are incomplete and architecturally unique. This is not a product of assumption making but of investigation. Such systems survive and evolve through the generation of variety and the avoidance of tendencies towards homogeneity (entropy and its informational analogue). So, microeconomic behaviour cannot be assumed to be homogenous simply because no evolution can occur in the presence of homogeneity, only system death in a world in which the second law of thermodynamics operates.

The behavioural heterogeneity that we observe in real systems is due to the presence of a myriad of idiosyncratic ways in which specific agents apply meso rules. A meso rule may be widely adopted in a population with high fidelity and efficacy, but the environments faced by adopters may vary considerably. This results in micro variety that, in addition to providing a very heterogeneous set of good and services, can yield meso rule adaptations through a process of learning and selection. However, it is clear that theorizing about the emergence of new and adapted generic rules and change in meso populations of carriers cannot involve formal analysis, nor can the resultant economic outcomes be described in terms of formal analytical solutions. All formal deduction requires structure to invariant, i.e., all chosen elements and connections must be fixed. As we have noted, in evolutionary economics, this has given rise to a simulation/calibration methodology that allows us to study how heterogeneous agents to apply generic rules and shift from one generic rule to another when circumstances dictate that this is worthwhile.

However, once we think in terms of the micro-meso-macro framework, we cannot restrict our simulations to processes of selection (generally represented by replicator dynamics). It is also necessary to explore the self-organizational processes of learning by doing and incremental innovation as the meso population of rule carriers increases. Furthermore, the consequent flows of microeconomic value yield aggregate income/expenditure flows at the macroeconomic level and, in turn, these flows feed back into the decision making processes of individuals. So we have a two-way value flow interaction between the microeconomic and the macroeconomic that has, at its base, an interconnected set of meso rules.

3. A Methodology

So how can we design a methodology that is consistent with the micro-meso-macro framework? What we shall argue is that simulation/calibration is not, by itself, an adequate methodology to provide powerful explanations of economic phenomena although it has an important role to play. In the absence of access to controlled experimentation (as must be the case in macroeconomics), the explanation of movements of economic data over time requires a methodology that is aimed at the discovery, not of the detailed specifics, for example, of firm behaviour, but of general principles that operate robustly and reliably for considerable periods of time. We shall look first at the meso, then the macro, and finally the micro despite the fact that economists tend to think that we should start with the micro.[10]

[10] This is obviously true of neoclassical economists but it is also true of many neo-Schumpeterian evolutionary economists who devote too little attention to the institutional context (the meso) and relatively little attention to Keynesian features of the economic system as a whole (the macro).

The meso

Having identified a research question, the first step should be to examine the history of the economic entity and its components over the chosen time period of the investigation.[11] The goal is to identify the different kinds of generic rules that enable value-generating connections between the components of identifiable systems. Case studies may be necessary to augment the historical accounts that are available, particularly at the firm or industry level. The most easily observed generic rules as meso units are laws that receive popular assent. However, it is often tacit norms and conventions that are crucial. We know from the outset that there are always localized and specific generic rules with very small carrier populations - these are quite diverse across the economy and generate value in a manner that can look stochastic in aggregated data. The order and associated continuity of structure and process that we observe over time in the economic system is due to the adoption and use of a set of widely held generic rules as stable meso units. If such well-established meso rules are fundamental complements to the production and consumption of a wide range of good and services, then their populations will not change significantly. However, we know that meso rule populations grow and decline and, with them, the set of heterogeneous outputs.

Economic growth is the product of widely observed diffusion processes that involve meso rule connections (order) spreading across a population. A myriad of local modifications, generated by learning by doing and incremental innovation, yield heterogeneity in productive processes and products. Economic decline involves the onset of disconnections (disorder) in systems where the capacity to generate new processes and/or products has been exhausted. Unlike the diffusion process, this is unlikely to be smooth because meso structures built upon generic rules cannot be easily reversed and have to be abandoned. It is also for this reason that structures that have reached their growth limit are often rapidly absorbed by other meso rule carrying structures that are more efficient or adaptable, through take-over and merger. Industry shakeouts are common (Klepper (1996)), as is the rapid demise of a good designed in line with a short-lived fashion. Only careful historical study over the chosen time period can enable us to understand these population dynamics and how different populations interconnect. We need to know which generic rules form stable meso populations and which are subject to significant population change over the period of investigation.[12]

[11] This is likely to be data determined.
[12] Care has to be taken in such investigations not to confuse fads and fashions (short-lived meso rules) with core meso rules that are pervasive over the period in question and likely to continue to be so beyond.

A precursor to this kind of meso rule perspective can be found in Foster's (1992) econometric study concerning the determination of British monetary magnitudes. It was found that what we would now identify as two meso rules seemed to be fundamental in the monetary process under investigation: one was the prudential regulatory and associated lender of last resort arrangements managed by the central bank and another was the conventional rules adopted by banks in their lending processes. The chosen explanatory model was built upon the observation that these rules seemed to be quite stable over the historical period in question, although, in the econometrics, some allowance was made for some drift in the application of these rules. Once the core meso configuration of rules had been identified, implied relationships between aggregate time series variables were identified. To this core were added hypotheses concerning the role of 'price' variables of the kind suggested by conventional economic theory. Importantly, the inclusion of such variables was justified by the observation that a workable market existed, i.e., a meso rule with a population of traders – in this case in a well-regulated short-term money market. The resultant 'evolutionary macroeconomic' model proved to be much superior to conventional demand for money based models both in explanation and prediction. Further historical investigations revealed that, because of colonial and post-colonial connections, Australians had adopted very similar meso rules in their banking system and, in Foster (1994), remarkably similar econometric results were found, using a model that was only adapted in relatively minor ways to account for what were mainly demographic and property market differences (due to climatic and geographical variations).

Despite the fact that a robust explanation of the growth of monetary magnitudes had been discovered, relatively little attention was given to these findings in the relevant macroeconomic literature largely because they were not built from economic theory in the conventional way. What we would now view as a generic rule approach based about meso units was not of interest outside a relatively small group of institutional economists who also had an understanding of econometric modelling. Foster and Wild (1999a) went on to take a similar approach to modeling monetary (non-bank) time series data emanating from an observable diffusion process, following a regulatory (meso rule) change. Again, this approach was found to be significantly more successful than one based on conventional theory and methods and, paradoxically, offered evidence of much more clearly identified 'price incentive' effects. Unlike the previously cited study, this one allowed for a changing population of meso rule carriers. This study was also largely ignored by conventional economic modelers but did generate interest amongst neo-Schumpeterian economists because of the logistic diffusion process identified.

Although these studies involved models constructed from meso rules, identified by historical study, a full micro-meso-macro methodology was not adopted. In particular, the heterogeneity of microeconomic behaviour and the associated adaptation of generic rules for local application (adding variety to the meso population) were not addressed. So, although good explanatory econometric models were obtained, no understanding of the underlying process, whereby heterogeneous economic agents adopt and adapt generic rules to generate stocks and flows of economic value, was obtained. From the perspective here, a 'meso-macro' approach was adopted. This is an important deficiency because it permits conventional economists to conclude that the chosen methodology does not contribute to advances in theoretical understanding, beyond some add-ons drawn from conventional theorizing. However, before we address this matter properly, the macro dimension of the methodology that we are suggesting requires discussion and development.

The macro

Aggregate time series data provide useful information about key connections in the economic system. They offer a particular kind of history. For example: aggregations of value, in income or expenditure form, flowing from heterogeneous economic processes; aggregations of the value of economic structures, as measured in asset and liability valuations; series of prices that are often weighted averages of many price indices; aggregations of inputs and output quantities, often computed using price deflators; aggregations of qualitative factors, such as numbers of patents or indices of consumer sentiment. It is well known that there are serious aggregation problems in connecting theoretical representations of heterogeneous microeconomic behaviour with macroeconomic aggregates. As noted, the conventional solution in modern macroeconomics is just to pretend that all microeconomic behaviour is homogenous and deal only with a 'representative agent' operating under very strong and unrealistic rules, some of which may be relaxed in thought experiments. Essentially, what such a methodology involves is a theoretical starting point that is a fully connected network of identical sets of components across all space and all time, and, moreover, one in which the meso domain of rules is given and invariant. A universal rule, constrained optimization approach, is employed to ensure that an equilibrium outcome can be defined on the basis of logic.

However, such a methodology is not concerned with the actual processes that underlie the historical data under consideration, not is the architecture of the structures that enable such processes to occur of any direct interest. In the real world, economic structures are networks of components with sparse connections that can increase or decrease in number. Connections can be local or long distance, involving only a few or many elements. For (dissipative) structures to survive, they must operate within a set of meso rules. But economic structures must also have operational micro rules to deal with specific aspects of production processes and product characteristics. Thus, we can think of the value that is generated at the heterogeneous microeconomic level as being separable into two components at some defined level of aggregation and defined time period: (1) there is the 'order' effect of widely held generic rules forming meso units, and (2) the 'complexity' effect of system specific operational micro rules. The existence of the former will show up in aggregate value data, both in autoregressive tendencies, because of the persistence of meso rules, and in enduring statistical associations between aggregate variables. The latter involves operational micro rules that are connected hierarchically with generic meso rules but are very heterogeneous and disconnected on the periphery of systems. The value generated on the periphery is subject to constant change, as incremental innovations and learning by doing results in novel micro rules that are embodied in new products and processes while old ones are discontinued. This is reflected in statistical noise in aggregate value data. However, components (1) and (2) are connected because some micro rules become new meso rules in the form of new institutions while old meso rules are abandoned. Equally, micro rules depend, critically, upon the existence of stable populations of meso rules. These micro-meso interactions are the source important shifts in aggregate associations and fluctuations in autoregressive parameters.

So, underlying time series relating to processes and outcomes in particular economic structures is a mix of generic (meso) and idiosyncratic (micro) rules that produce a mixture of auto-regressive tendencies and fluctuations in aggregate data. And this is what we typically see: we observe time series following paths that, superficially, are like either random walks or random walks with drift (Ormerod (2005)). As is well known, series with unit roots are historical in nature that cannot be viewed as deviations from some equilibrium value and the frequency with which they occur suggest that we should take a historical approach to understanding them (Freeman and Louca (2001)). However, conventional econometric modelers do not do this but instead, seek to remove the autoregressive component of a time series by ‘first differencing’ it to render it ‘stationary’ in order to focus more clearly upon the associations between time series. In doing this, they eliminate a key connection between the data and the meso rules that are the source of economic value as well as key variations in the two way relationship between meso and micro rules.

As Foster and Wild (1999b) point out, from an evolutionary economic perspective, this involves the removal of very important information concerning the role of meso rules in maintaining and growing economic value over time. In particular, the impact the spread of new generic rules, and associated incremental innovation and learning by doing and of increases in the numbers of rule carriers, is ignored despite the widespread observation of value trajectories following logistic diffusion curves. Furthermore, structural discontinuities in time series models are ‘patched up’ by various *ad hoc* ‘regime shift,’ ‘break-point’ and ‘regression switching’ techniques rather than investigated through proper historical inquiry.

Lets us think about aggregate data and underlying economic processes from an evolutionary perspective. Value flows registering in macroeconomic data emanate from processes in dissipative structures in the following simple way:

$$X = X_{-1} + X_N - X_S \qquad (1)$$

Where X_N : new value from the application of new meso rules and/or increased use of existing meso rules

X_S : loss of value because of the abandonment of old meso rules and/or the reduced use of prevailing meso rules

X_N and X_S cannot be zero, because it would be an untenable state for any dissipative structure to be in because of the second law of thermodynamics. $X_N = X_S$ is also untenable as an enduring state because the nonlinear nature of entropy processes ensures that it is a structurally unstable state, i.e., eventually X_S will exceed X_N. If X_N and X_S are random, and $X_{-1} > 0$ then we get a classic random walk. The random walk hypothesis is often supported in time series data over certain periods, particularly in the case of financial asset prices.

However, in evolving economic structures, X_N and X_S are not random, they are the outcome of managerial and/or entrepreneurial decision-making (or lack thereof). Following the entropy law, X_S has a component that is related to X_{-1} because of component and connective wear out, for example, because of the breakdown of technological rules in physical assets. Thus, firms anticipate this in their depreciation provisions, e.g., in value write-downs. This results in planned replacement investment. However, this need not just be a negation of X_S but also an addition to X_N, inasmuch as replacement capital goods embody new technological rules.

The biggest problem is the loss of *relevance* of productive structure – both technological and organizational rule obsolescence lead to unanticipated rises in X_S which can be fatal in an economic structure which is not generating enough X_N through the application of novel generic rules. Thus, new investments in capital goods, human capital and organizational structures always have to have an element of entrepreneurship if the productive organization is to survive. So, although some of the decline in new value and the increase in new value is linked to X_{-1}, some value change is uncertain – there is unplanned obsolescence of existing structure (and associated rules) and the generation of new structures embodying entirely new rules:

$$X = X_{-1} + n X_{-1} - s X_{-1} + \boldsymbol{u} \quad (2)$$

or

$$X = X_{-1} (1 + n - s) + \boldsymbol{u} \quad (3)$$

Where **u** is the combined value associated with X_N and X_S, that is unconnected with embodied meso rules in existing structure.

If ***u*** happened to be random (often presumed to be a reasonable assumption in evolutionary biology) and *n* is not equal to *s*, we would have a random walk with 'density dependent' drift. For growth to occur, *n* must be greater than *s*. But, this growth cannot go on forever – we observe a 'developmental' or 'self-organisational' rise in value that tends to a limit often characterized as a logistic growth path. This implies that *n* and *s* are not fixed parameters for the simple reason that density dependent growth occurs because of incremental innovation and learning by doing which must, eventually, run out if the is not a shift to the application of a radically different meso rule.

Thus, for a logistic path to exist $n - s = b(1- X_{-1}/K)$, where b is the logistic diffusion parameter. However, this is limited to growth up to the point where $n = s$ or, equivalently, where $X_{-1}=K$. If conditions arise where worn out structure is not being fully replaced ($n < s$) then a downward spiral of decline will set in. So, whereas $n > s$ is a state where there is full replacement of worn out structure plus incremental innovation/ learning, $n < s$ is one where exponential decline is inevitable.

Once we account for the incremental application of meso rules, i.e., self-organisation, $\boldsymbol{u}$ is likely to be more random in character. However, over the time span of a logistic curve, $\boldsymbol{u}$ is still likely to be non-random because arrival and departure of meso rules and their diverse applications is not random. The adoption of new meso rules in favour of old ones is most easily enacted around the point of inflection on the logistic when value is growing fastest and surpluses for investment tend to be largest. In contrast, it becomes very difficult to shift meso rules (as a stable population, or institution) when a growth limit is attained. Thus, the variance of $\boldsymbol{u}$ is not likely to remain constant, either in its oscillatory characteristics or in its variance (Foster and Wild (1999b)), i.e, we cannot presume that $\boldsymbol{u}$ is Gaussian.

So we can see that there are interesting features to be discovered in aggregated data, given the connections that exist between meso rules and value generation. Understanding the statistical properties of relevant macro time series data and the associations between them can, therefore, provide important information to compare with prior findings concerning meso rules obtained by historical and case study. Now, investigation of the statistical properties of time series is already practised in standard econometric methodology, albeit from a very different theoretical standpoint. We can identify if time series over a particular period are stationary or non-stationary and whether a trend is deterministic (linear or nonlinear) or stochastic (or both) with or without time drift. From our standpoint here, deterministic trends are indicative of the operation of meso rules in generating historical path dependence. In addition, co-integration tests establish the degree of connectivity between time series which, again from the standpoint here, suggest that there are component connections in network structures due to adherence to meso rules. For example, we may observe path dependence in a measure of output, perhaps a logistic path, and we may also find co-integration with an input measure. Conventional economists would tend to see this as indicating the existence of a ‘long run equilibrium’ production function. Shifts of this presumed function might then be attributed to exogenous technological change. From our perspective this co-integration could be viewed as indicative of the operation of meso rules, with a non-stationary, non-equilibrium diffusion process operating in which technological and organizational change are endogenous.

A statistical examination of the properties of available and relevant series and the connections between them can yield information about the possible existence of generic rules forming meso units as well as variations in the populations of rule adherents. Once these statistical associations have been identified, qualitative evidence, already compiled through historical and/or case studies can be compared. We can then proceed to eliminate meso rules that seem to have no counterpart in the time series data that we have at our disposal and we can also eliminate time series and connections between time series that have no obvious link with identified meso rules. A parsimonious model can then be constructed and estimated econometrically. What we then have is not only time series data but also estimated parameters concerning the connections between time series consistent with the operation of underlying meso rules. It should be stressed that this is not just ‘sociology’ – in economic investigations the most important meso rules are those, for example, concerning the collective acceptance of market structures and adherence to formal and informal contractual obligations. This means that quite conventional relationships involving prices, incomes and quantities are likely to play a significant role.

The micro

The problem with the parsimonious approach outlined is that it cannot span phases of rapid transition when meso rules rapidly lose their populations. Regression is, essentially, an averaging technique that cannot easily encompass non-average behaviour. This problem was encountered in Foster and Wild (1999a) and investigated through a residual error decomposition approach in Foster and Wild (1999b). Evidence was produced that the oscillatory behaviour of residuals and the variance of these residuals revealed certain patterns prior to structural shifts (in the case in question, because of regulatory changes). This seemed to be useful because it suggested that it is possible to get an ‘early warning’ that a system is due to stop growing and enter a phase of structural instability. However, by necessity, the microeconomic behaviour that gave rise to such transitions is left firmly in a ‘black box’. It is for this reason that conventional economists tend to look at this kind of research and argue that it lacks theoretical micro-foundations. And they have a point because, although the meso remains the driver of microeconomic behaviour and the generation of value, ultimately, we need to know about the motivations that give rise products and processes at the microeconomic level and how these motivations eventually result in structural transitions.

It is here that simulation/calibration is very useful since it is immediately clear that, in the evolutionary setting that we are envisaging, there is no possibility of finding analytical solutions in the traditional way. But we can construct simulations of how agents use meso rules to devise heterogeneous ways of generating economic value. Since we can never disentangle this empirically, we can only seek theoretical propositions that can summarise the processes involved and discovered these through simulation/calibration.

The first step is to use historical study to identify the appropriate definitions of the agents involved, following, for example, Malerba et al (2001). However, unlike in the latter study, this methodology does not seek specific details but, rather, general characterizations of economic agents and how they behave and interact with each other. There is no reason why the logic of neoclassical microeconomics and game theory should not be used here, provided that it is appropriate to the decision environment faced by a decision-maker. It is essential that the characterization of behaviour chosen is realistic within the meso-rule structure that has been found to exist and has a counterpart in sets of economic data.

The main difficulty faced by all simulator/calibrators, is to justify the parameters used in simulations. Critics argue that the judicious selection of parameters can allow many different simulations to calibrate on the same data. In the methodology proposed here, selection is restricted. The chosen parameters must, ultimately, be consistent with the econometrically estimated parameters connecting relevant time series variables. So calibration is not primarily on the raw time series data but on the statistical associations between time series, reflecting the existence of significant meso rule populations. But we know that estimated econometric parameters only make sense when there are no structural discontinuities. The most stringent test of a simulation is to extend it beyond the estimation period across a discontinuity and examine if it is capable of calibrating on the data. This is a very difficult test. It is based upon the presumption that the seeds of discontinuity are present even when value is growing in a stable way. In other words, there must be aspects of behaviour in the good times that contribute to the emergence of bad times.[13] What this methodology, then, seeks to do is deal with non-average behaviour through simulation by utilizing evidence of average behaviour offered by econometric modeling.

What such simulations can achieve is an analytical understanding of microeconomic behaviour in the face of a set of meso rules. In a sense, it can be classified as inductive theorizing but 'abductive' (see Josephson and Josephson (1994)) is more appropriate because the econometric modeling involved uses some deductive reasoning concerning the properties of dissipative structures and some traditional deductive reasoning. The agent based simulation design is also likely to involve some logical reasoning, i.e. some appeal to rational behaviour, however incomplete or bounded, is likely to be applied. The goal of simulation/calibration of this kind is theoretical: the quest is to discover recurring theoretical principles operating in a range of different circumstances using a methodology that is firmly connected to the identification of rules in history and statistical relations in historical data.

In conventional economics, fluctuating time series are frequently modeled analytically using dynamic mathematics. Indeed, this approach has almost become the core of modern macroeconomics. However, it is a fundamentally mistaken theoretical approach because time series data do not actually measure behavioural processes but instead are only an aggregated value manifestation of such processes that are inherently complicated. What the micro-meso-macro methodology offers is a way of obtaining simplified, i.e., truly theoretical, representations of actual complex processes by taking a four level approach: historical/case study; time series statistical investigation, parsimonious econometric modelling, micro-simulation/macro-calibration.

This is markedly different to conventional modeling in three ways: first, non-stationarity in time series, which conventional modelers desire to eliminate in order to focus upon supposed 'equilibrium' relationships, is viewed as crucially important and reflective of the meso rule structure that drives economic activity; second, *heterogeneous* microeconomic behaviour is dealt with explicitly and theoretically; third, the methodology embraces uncertainty, path-dependence and the success and failures that characterise economic evolution - there is no

[13] For example, if a firm distributes too much profit and under-invests when growth is high, it will, undoubtedly run into difficulties if its market saturates (Foster (1986)).

escape into a non-existent world of abstraction yet, at the same time, there is no appeal to 'irrationality' in the choices that people make.

4. Conclusion

In this paper, we have offered a methodology for evolutionary economic analysis that seeks to combine computational, historical and econometric methodologies into an integrated methodology built upon the micro-meso-macro framework. We think that this approach is superior to simulation/calibration approaches in new classical macroeconomics, in the dynamical economic approaches to be found in neoclassical, and post-Keynesian and new Keynesian analysis, and also in the historical/case study approach of institutional economics. To a large degree, our methodology encompasses what these approaches seek to do in a unified framework. Simulation and calibration are therefore not ends in themselves, but useful items in an analytical toolkit that can help us understand the structures and processes that we find in economic reality. We think that economic structure is both ontologically and analytically best represented as a complex system of generic rules forming meso units and that the methodology discussed reflects this. And, as we have argued, this involves a hybrid methodology of historical investigations, case studies, statistical analysis, econometrics modeling and simulation/calibration. The economy is a complex adaptive system and so we should not be surprised that its features cannot be adequately revealed with the prevailing 'simplistic' methodology.

In moving towards such a methodology we are, of course, shadowing the insights of others. The notion of meso rules and their emergence and decline owes much to Hayek and his notion of spontaneous order, the diffusional character of meso rule adoption and application is closely connected with Schumpeter's insights and the unique role of knowledge in economics goes back to Marshall's vision of how the economic system works. Also, Hayek wrote about patterns of rules and their enduring qualities. In this regard, the methodology that is proposed offers potential as a basis for mapping the generic structure of the economy.

Aside from more exotic quests of this kind, we believe that the proposed methodology should be of interest and relevance beyond evolutionary economics. We know that difficulties in relating macroeconomics to microeconomics have posed serious problems in modern macroeconomics and that these problems are, at base, methodological in character. But it is also the case that evolutionary economists have relatively little to say about macroeconomics. This is commonly justified on the ground that aggregation averages out all the non-average variety that is the fuel of economic evolution so that there is little of interest left. However, the complex systems approach challenges this presumption on the ground that we must understand where variety comes from (Foster and Metcalfe 2001). We argue here that the evolutionary economic process is driven from the meso, even though micro agents are the source of all ideas (and, therefore the rules that may then form into meso units) and the domain of all economic actions and operations. If this is accepted then it must be made explicit in the methodologies that we use.

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