

The allocation of complexity¹

Jason Potts, Kate Morrison and Joseph Clark

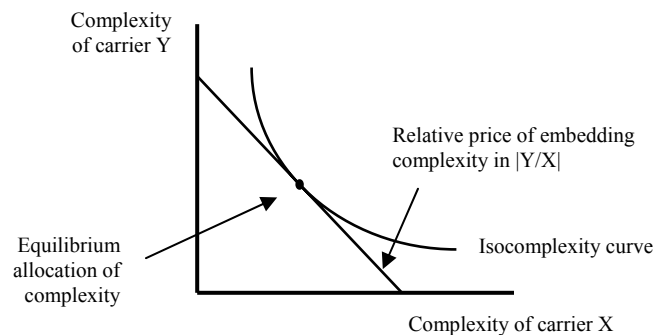
School of Economics & ACCS, University of Queensland, Q4072, Australia.
j.potts@uq.edu.au, j.clark@uq.edu.au, kate@katemorrison.com,

ABSTRACT: Much thought and effort has gone into the design of new conceptual frameworks and theoretical tools for the analysis of evolving, self-transforming economic systems. Nevertheless, why not follow Marshall?

In this paper, we present a novel but not unfamiliar way of analyzing the complexity of economic systems as the outcome of a self-organizing process. We shall propose a comparative static framework for analysis of the allocation of rules between different classes of carrier. We start by *assuming complexity* (i.e. that evolutionary forces maintain complexity in open systems), and then analyzing the distribution of state-space equilibria under different relative costs (prices) of embedding rule-complexity in different systems, such as between agents or institutions.

The outcome is an *allocation of complexity*. Changes in relative prices, as caused by technological, institutional or financial innovation, say, will effect the position of the equilibria in carrier-space. We may, therefore, study how changes in the cost of embedding rules conditions the evolution of the complexity of an economic system.

The upshot is a set of simple tools for arraying economic forces over the different dimensions of economic evolution in order to study the effects of relative price changes on the dynamics of economic evolution. The use of complexity as a conservational concept (and its derivative, a convexity argument) may prove expedient for further theoretical and conceptual development of economic analysis. The generic graphical model, a possible bridge between neoclassical and complexity economics, is as such:



¹ Thanks to seminar participants at (1) *Organizations, innovation and complexity – New perspectives on the knowledge economy*, NEXUS-CRIC Workshop, University of Manchester, 9–10 Sept 2004; (2) *Shifting boundaries: Governance, competence and economic organization in the knowledge economy*, Bristol Business School, 2–3 Sept 2004; (3) ECG/ACCS seminars, UQ...

‘If the trading rules are smart, the traders need not be.’

– Gode and Sunder (1997: 623)

1 Introduction

When Alfred Marshall wrote his *Principles*, he intended it as volume one of a two volume set, the second to be devoted to analysis of economic dynamics and the long period. Rather than being based in mechanics, as was his first volume, he imagined the second volume very much based in biology and in evolutionary theory. It was to be the theory of the evolutionary dynamics of market capitalism. Yet Professor Marshall never quite got around to delivering on this, and modern evolutionary economists have never really forgiven him this breach.

Unaccountably spurned, they have turned instead to the likes of Veblen, Schumpeter, Georgescu-Roegen, Prigogine, Kauffman and other exotic meta-theorists of open-system dynamical processes. Modern evolutionary economists now actively distance themselves from neoclassical economics in general and from comparative statics in particular because, it is argued, evolutionary analysis is inherently about non-equilibrium historical processes of endogenous transformation, and that such processes are, by definition, supposedly, unable to be represented in a comparative-static equilibrium-based framework. Yet we shall propose that a comparative static method of evolutionary economic analysis can be sensibly developed with Marshall’s toolkit, and maybe, perhaps, his second volume might have looked more like his first had he grasped the significance of the allocation of complexity problem.²

In modern evolutionary economics, an economic system is conceptualized as a system of meso units, with each meso unit the population of actualizations (or carriers) of a generic rule. Economic evolution is then defined as a process of change in the meso population of rules. The micro–meso–macro analytical framework (Dopfer *et al* 2004) reveals the underlying structure of economic evolution as a meso trajectory, and frames analysis of this process in terms of micro and macro domains. However, no account has yet been given of the economic nature of the complexity in this process, and, in particular, of the allocation problem of rules over carriers.

What, in other words, are the ‘economics’ of economic evolution?

This is, we suggest, bound up with a proper understanding of the role of complexity in economic systems. And this, we shall argue, is an allocation problem: the allocation of complexity. Evolutionary economists normally emphasize complementarity and connective structure (e.g. Potts 2000). But we propose that economic evolution can also be considered in terms of substitution and relative prices. This perhaps somewhat curious feat is achieved by recasting the prime dimensioning of economic analysis into the terms of comparative rule-complexity of agents and institutions, or, more generally, of ‘carriers’. The economic system is a rule system: carriers carry rules.

The economic system is a rule-system and the economic process is a rule-process. The dynamics of the economic system are structured by the relation between rules and carriers. From this premise, we may then isolate a classic allocation problem in the substitution relation between two generic/primary carriers of complex rules – agents and institutions – as a function of the relative costs of embedding rules in these carriers subject to the constraint of maintaining overall system complexity.³ A change in the relative cost of embedding rules in different carriers (i.e. agent and the environment) will work to redistribute rule complexity between them, but how? This is the allocation of complexity problem.

Our fundamental premise is that complexity is carried in two fundamental classes of carrier – agents and institutions – and that there is a difference in the cost of embedding rules in each. This concept of differential carrying of complexity, and therefore of a distribution of complexity, thus becomes the

² As, among others, John von Neumann, Ronald Coase, Friedrich von Hayek, Herbert Simon, George Shackle, Douglas North, Brian Loasby and Vernon Smith were later to do. See Mirowski (2002).

³ As a scale free measure between both micro and macro.

allocation of complexity problem precisely when there exists differentiable costs of carrying complexity between carriers; in other words, a relativity or substitution relation. We propose that a framework of comparative statics may be used to analyze the distribution of complexity carried by an economic system and, as well, how this changes as an evolutionary process.

Section 2 introduces the relationship between rules and complex systems. Section 3 discusses the idea of complexity as a solution concept. Section 4 resents this in terms of the allocation of complexity problem. Section 5 completes the framework with the construct the relative price of complexity. Section 6 applies isocomplexity theory to three levels of evolutionary economic analysis (micro–micro, micro–meso, meso–macro).

2 Meso rules make for complex systems

The economic system is made of rules. It is a complex rule-system that is, at once, both a network and a population story. This is the essence of the meso analytic perspective. Subsequent research has revealed some further analytical structure. In prime instance, the economic problem of differential rule evolution is outlined in the specific context of consumer choice in Earl and Potts (2004), the conceptualization of generic rule evolution is set out in Dopfer and Potts (2004), and the micro–meso–macro framework is presented in Dopfer, Foster and Potts (2004).

A rule, or meso unit, is a *generic idea* and its population of *actualizations* in carriers. Beneath the surface phenomena of production and exchange by people of things lies the deep structure of knowledge as a complex system of meso rules.

Economic evolution is the process of coordination and change in these meso rules along a *meso trajectory* of origination, adoption, adaptation, retention and maintenance. A meso trajectory begins as a disturbance that will eventually arrive, via a creative-destructive process, at a meta-stable state of coordination (micro) and order (macro) with respect to other meso rules.

The meso-centered analytical framework allows us to model economic evolution as the self-transformation of a complex rule system. It links together evolutionary economic analysis of population dynamics and structural change, and of agent learning and emergence of institutions, into a unified framework. It connects population and statistical arguments together with arguments about complex structure to provide analysis of evolutionary processes. It is based on the coordination of complex systems, yet it leaves the economics of this, we think, unnecessarily unstated. A basic assumption of the micro–meso–macro framework of economic evolution is that rules are embedded in the economic system, yet Dopfer *et al* make no attempt to tease out the specific form in which they are embedded, nor to account for the economic forces that effect the allocation of rule complexity over carriers. We propose, then, that the allocation of complexity framework can be used to analyze the rule substitution processes interior to a meso trajectory.

A rule can be carried or, equivalently, embedded, in different ways: i.e. the complexity of the economic system can manifest in various structural forms.⁴ A technology, for example, could be embedded largely in the cognitive abilities of human agents or largely in commodities or institutions. Smarter agents enable the same level of complexity to be achieved in a simpler environment, and a smarter environment may achieve the same with simpler agents (Omerod 2004). But what determines which path will be taken? What determines this distribution of rule complexity?⁵

⁴ Earl and Potts (2004) have recently illustrated how choice itself can be considered in this way when decision complexity leads boundedly rational consumers to outsource decision rules to market environments. Their ‘market for preferences’ concept can be viewed as an allocation of rule complexity problem, when the rules are inputs into a decision heuristic conceived along an isocomp.

⁵ One might reasonably suppose that the answer to this question is transactions costs, in the Ronald Coase or Oliver Williamson. Isocomplexity theory is more aligned with Coase’s original conception of alternative coordinating institutions over systems domains (a la Hayek 1945, 1960) rather than Williamson’s (1975) development of the idea into statements about bargaining games, i.e. opportunism with guile, etc. We suggest that isocomplexity theory provides a more general theory of this process, by taking into account the costs of embedding rules in a system, as

The allocation of complexity problem is about the distribution of the population of a generic rule over different classes of carrier. Rules carried exclusively in one class of carrier are, obviously, not subject to the allocation of complexity problem. But, if carried in this way, they are also unlikely to be generic *economic* rules in the first place. Following Foster (2004), we delineate economic systems on the basis that they are human-centric; that is, that the set of rules they comprise may be carried in agents *or*, definitively, proactively embedded in the institutional environment to which the agent itself is subject. To put it plainly, only human-based systems create institutions. While all natural systems – at both the human and smaller scales – exist within an environment, it is essential to recognize analytically that when humans are the primary scale at which agents are defined, the environment is agent-mutable. The agent-environment dichotomy always exists as the fundamental construct that underpins complex systems analysis, but we suggest that an allocation problem – that is, an economic problem – emerges only when choice over *where* rules are embedded also exists. This is not the case for biological non-human systems whose agents – genes, organs, butterflies, etc – are constrained completely by their environment, precisely because these agents cannot exercise choice over the rule-composition of their environment in the way that human, and more specifically economic, agents can.

The science of economics relies fundamentally on the notion of human choice; we posit that the proper analysis of economic systems (or other human-based systems, be they social, political or cultural) must rest on recognition that human agents have the unique capacity to externalize rules by choosing to embed them in their environment. It is the systemic consequences of such rule-embedding choices that we herein seek to illuminate with the theory of the allocation of complexity.

An economic system is an ‘artificial’ system of high-order complexity (Simon 1979, Foster 2004). Complexity is manifest in the variety of structural forms that a rule can be carried: rules are fungible with respect to carriers. For the greatest part, meso rules in the economic system are embedded across at least two classes of carrier (although for ease of exposition, we shall presume just two for the moment: agent and environment).

The complexity of the meso rule system is decomposable over these carrier classes, where each carrier class has varying levels of complexity. Agents may be very simple or highly complex. The environment may be very simple or highly complex. The set of all combinations of a meso rule over carriers is mapped by what we call ‘meso-space’ or ‘carrier-space’. At a point in time, the complexity of a meso rule is carried, in part, by the complexity of the agent, and, in other part by the complexity of the environment. The complexity of a meso rule is always, in some measure, allocated between agent and environment.

3 Assume Complexity

Along with a specific conceptual understanding of the economic system as a complex rule-system, our theory is also based a specific analytical assumption about the nature of this complexity. We shall suppose that complexity is a solution concept.

Indeed, it is our argument that even from the ontological perspective, complexity is a solution concept. Complexity is a partial region of the potential state-space of a system, and therefore is a property a system may or may not have. A system may occupy one of many positions in the state-space continuum, yet only some of these states are complex. What is interesting about these states is that complexity seems to be an attractor.⁶ Viable economic systems in an open system environment are inherently complex, they cannot be otherwise and hope to survive and adapt. Evolution attracts systems toward complexity.

When we assume complexity we allow dimensionality to rule carries, and orthogonality to rules. We arrive at a new solution concept. As the deep forces of mechanics in closed systems work to

well as the ongoing costs of using them. Isocomplexity theory deals with systems costs generally, an of which transaction costs are a subset.

⁶ As Kauffman (1993) and others have pointed out (e.g. Potts 2000) in relation to the balance of forces of variation and selection, and as Prigogine (1979) and others have pointed out (e.g. Kay and Schneider 1994, Allen 2002, Foster 2004) in relation to the second law of thermodynamics.

maintain an equilibrium state, the deep forces of open system thermodynamics and evolution work to maintain complexity. The founders of the theory of fully connected market systems (e.g. Walras, Edgeworth *et al*) saw fit to suppose the long-run state of the competitive economic system is general equilibrium. This became, therefore, the starting place for analysis. We argue that the competitively maintained long-run state of a partially connected open-market economic system is general complexity.⁷ Complexity is a steady-state solution concept for an open system.

This is why we shall ‘assume complexity’. Kauffman’s hypothesis of evolution toward complexity, and the Kay and Schneider hypothesis of complex systems maximally degrading energy, both refer to deep forces that maintain a state of complexity in open systems processes. The growing evidence that real world systems exhibit small-world and scale-free properties (e.g. Watts 2003, Barabasi 2004) only reinforces the role of complexity as a structural attractor in the state-space of a system.

There are of course many reasons that a system will not be complex, such as to lock-in important structural features in the short run. But, when this happens, flexibility is lost somewhere, and this generally impacts negatively on the long run prospects of the rule. In an open system where flows of energy and information from the environment are always variables, and where the environment itself is subject to change, we should expect that the basic meso structure of an economic system will be structurally complex, and not otherwise. Economic systems are complex because, in essence, they could not have evolved if composed otherwise (see Simon 1969).

4 Allocation of Complexity

‘The ‘boundedness’ of our rationality is expressed not by some imaginary divergence from optimality, but through the means and devices we access to think clearly.’

– P Mirowski (2002: 563)

We may decompose the distribution of complexity between rules embedded in agents (cognitive rules) and rules embedded in the institutional environment (artificial rules).

Rules	
Agent	Environment
Cognitive rules	Artificial rules
Subjective	Objective

Both agents and institutions are in this sense carriers of rules. The complexity of an economic system $C(R)$ is distributed across the complexity of agents $C(A_R)$ and the complexity of the environment of institutions $C(I_R)$ as such:

$$C(R) = C(A_R) + C(I_R).$$

⁷ A further way of treating complexity, recently proposed by Foster (2004), is with the notion of an economic system as being 4th order complex (dissipative physiochemical systems are 1st order complex, biological systems are 2nd order complex, social systems are 3rd order complex). The emergence of higher order complexity turns on the emergence of new ways of acquiring and using energy through ever more complex systems of knowledge and interaction. An economic system is 4th order complex in that agents must not only form mental models of the environment (3rd order) but also of each other mental models. This is apparent in such things as contracts and other market institutions.

Agent rules refer to the cognitive, behavioural and interactive capabilities and actions of an economic agent. Economic agents are, in this sense, rule-using and rule-making carriers (Dopfer 2004). Examples of agent rules include skills, habits, routines, capabilities and other such instances of rule-behaviour. Institutional rules are the artificial (or artifactual) environment of the economic agent, and consist of the set of meso rules the agent is connected to. Examples include contracts, capital, commodities, organization, institutions and so forth. An economic system is a complex system of agent rules interacting with environment rules in a coordinated manner. Isocomplexity theory seeks to decompose this relationship.

The allocation of complexity across rule-carriers assumes a 2-d rule-space we shall call meso space. Any system of rules R will be distributed between agents (A_R) and institutional environment (I_R).⁸ Consider Figure 1 below, in which carrier dimensions of agent and environment are set out along orthogonal axes of increasing rule complexity. Each point in meso-space represents a hybrid rule-system across agents and institutions at varying levels of carrier complexity.⁹

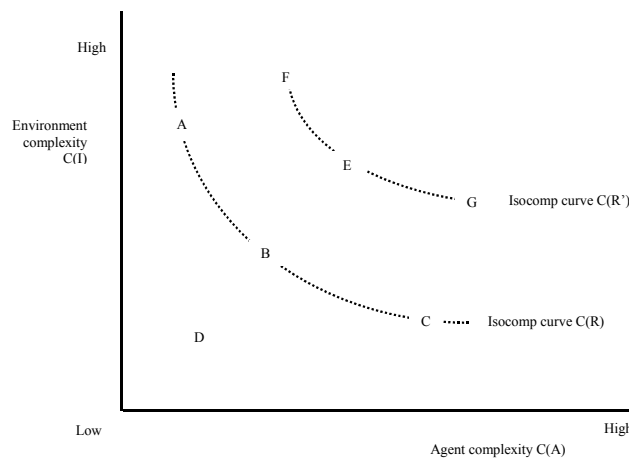


Figure 1. The carrying capacity of rule-systems by the complexity of agents and environment is mapped in meso space. ABC and FEG are a convex maps (isocomp curves) of constant complexity in meso rules $C(R)$ and $C(R')$ allocated over two classes of rule carriers $C(I_R)$ and $C(A_R)$. Isocomp curves have similar properties to indifference curves.

The nature of the space is conceptualized as such. Point A has high complexity in the institutional environment and low complexity of agents. This might be an economic system in which there is a high degree of organization in the environment, with each agent highly specialized, but not very complex otherwise. A Fascist state would be an example, as would a beehive. Point B has the same overall systemic complexity in the meso rule, i.e. the same problem-solving capabilities as an aggregate system, but this is achieved with a lower level of institutional complexity compensated for by greater complexity in agents capabilities (e.g. learned rules). This might be represented by a well educated population in a more rudimentary environment (e.g. Japan after WWII, or Russia after the collapse of communism). Point C continues along this overall complexity invariance function, and might represent highly capable agents in a very primitive environment (as in the reality TV show *Survivor*, or Western businesses expanding into emerging markets). Point D corresponds to simple agents in a simple environment

⁸ The algebraic properties of meso space derive from the set-theoretic conception of the carrier dimensions. It is unclear to us whether it is reasonable to assume these to be real valued. It would certainly be convenient. At the risk of unhinging the analysis before it starts, let us make that a point for mooting.

⁹ We immediately rule out corner solutions by assuming that there is no such thing as an economic system purely made of agents, and similarly, no such system purely made of environment. An economic system is a system of economic systems, and each economic system consists of a non-zero combination of both agents and institutions. All economic rules are embedded in both agents and institutions and are fungible between.

(human prehistory) and point E corresponds to complex agents in a complex environment (e.g. a modern first-world economy).

Contour lines of isocomplexity can be traced in meso space, as in the $C(R)$ level of complexity in ABC or the $C(R')$ level of complexity in FEG in Figure 1 above. We propose that a map of complexity equivalent rule substitution in carrier space is called an *isocomplexity function*. For example, the same measure of aggregate complexity can be achieved with highly complex agents in a simple environment, or simple agents in a highly complex environment, or some convex combination of the two. An isocomp represents the distribution of carrier-equivalent computational complexity about a meso unit.

A shift along an isocomp represents a change in the relative efficiency of carriers of a rule, and so leading to a rule being carried more by institutions rather than agents, as in Figure 1 above, with a shift from C to A, or E to F. This represents the process of institutional embedding. Substituting rule complexity from the agent to the environment enables simpler agents to solve the same problems by shifting embedding rules deeper into the environment. The entrepreneur-led processes of market-making or infrastructure building are examples of this, as is the role of mass advertising, or even political action. A shift along an isocomp is complexity invariant at the system level, but re-allocates complexity from one carrier to another. This will invariably be accompanied by structural change at the firm, industry or economy-wide level.

A shift in the isocomp, say from the locus of points though ABC to those running through FEG in the diagram above, represents an increase in the aggregate complexity of the rule-system. This is a necessary process in economic evolution as mandated by the second law of thermodynamics as applied to an open system. Increased energy throughput is achieved through increased complexity. But there are many ways this can happen. It is unclear what the distributive effect will actually be on the allocation of complexity in rules between agents and institutions.

Three possibilities from point B are illustrated above. An evolutionary meso trajectory B to E preserves the distribution of complexity, while a trajectory from B to F represents an institution-dominated growth of complexity, and one from B to G represents an agent-dominated growth of complexity. But what will happen is yet undetermined. All that we can say is that a shift in an isocomp, say from $C(R) \rightarrow C(R')$, represents an increase in the aggregate complexity of the aggregate rule system. A shift along an isocomp curve is meso complexity preserving. A shift in the isocomp curve corresponds to increased overall energy-transformation and/or information processing, or, in general, problem-solving, by an increase in the complexity of both agents and institutions.

The growth of knowledge and the growth of economic systems are but two sides of the same problem, namely of the allocation of complexity of rules between carriers.¹⁰

The normal direction of economic evolution is to increase both the complexity of institutions and agents as an overall increase in the energy or information throughput of the system. This will tend to correspond to an increase in the state of knowledge of the economic system. In general, the dynamical path of economic evolution can be traced out in this meso space. But, without some notion of relative costs or prices of complexity under different allocative conditions, this trajectory is as yet undetermined. The energy-complexity framework tells us the general direction upon which we should expect things to happen, but there is as yet no choice theory in this argument. For that, we need to consider the implications of a budget constraint on the allocation of complexity.

5 The relative price of complexity

Relative prices, or relative costs,¹¹ are introduced into this framework by considering the relative ‘price’ of carrying a meso rule variously in an agent or in the agent’s environment. As argued above, the existence condition of a generic rule is that a meso rule is always able to be substituted between agent

¹⁰ See Hayek (1945), Shackle (1972), Loasby (1999).

¹¹ Because each point on an isocomp corresponds to the steady state of a general equilibrium under competitive conditions (and so extensions to this framework arrive under conditions of imperfect competition), then each set of relative prices, under duality conditions, also corresponds to the set of relative costs.

and environment, and vice versa. As an isocomp is an attractor, we suppose that the equilibrium outcome will be in proportion to the cost of embedding complexity in the agent or environment respectively. The isocomp defines the topology of the allocation problem, but relative prices determine its solution.

[here on the meaning of the budget line...]

The relative price of complexity between in institutions and agents is given by the budget line $C(I)$ – $C(A)$. The slope of the budget line is given by the relative costs of carrying complexity (P_I/P_A). A steep budget line means that institutional carrier costs are relatively lower than agent carrier costs, and so that it is better to carry complexity of rules in institutions rather than in agents. A flatter budget line means that agents can carry the rule relatively more efficiently than can institutions. A fall in the absolute cost of complexity in both agents and institutions will shift the budget line out. An increase in the absolute cost of complexity in both agents and institutions shifts the budget line inwards.

Figure 2 below illustrates a shift in the carrying costs of complexity so as to make institutions carriers relatively cheaper rule-carriers than agents.

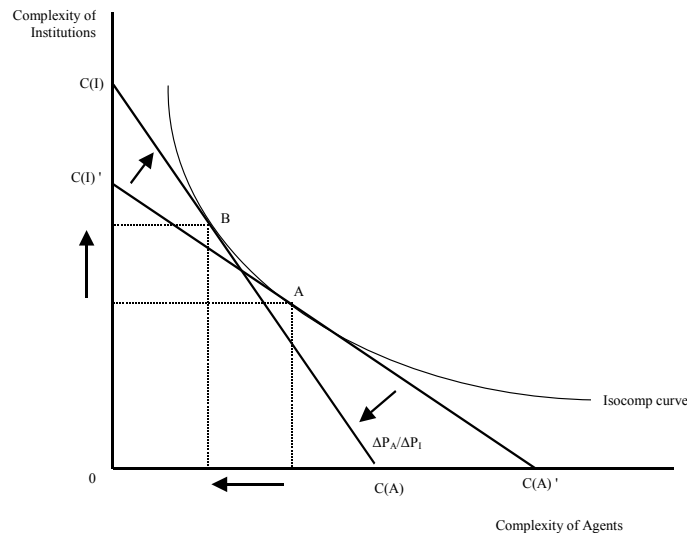


Figure 2. A shift in the budget line for carrying complexity. A fall in the complexity of institutions is compensated for by a rise in the complexity of agents.

A pivot in the ‘budget line’ as illustrated above might be caused by a change in the relative efficiency (or efficacy) of rule-carriers. But a shift (outward) of the budget line, as in Figure 3 below, would be caused by an absolute change in the efficiency and efficacy of rule carriers. Both sorts of change are induced by new meso rules.

What specifically happens will depend on the particular character of the novel generic rule and its relation to other meso. For example, the introduction of a new meso rule in the form of an improvement in technology, or market infrastructure, or agent skills will probably change both the relative costs of embedding and the absolute costs of embedding. Nevertheless, our analytical framework separates these into two components: relative and absolute price changes. An absolute shift corresponds to a new rule enabling a higher level of aggregate complexity overall, and therefore energy throughput, but without changing the underlying carrying costs. This corresponds to a shift out of the budget constraint to a higher isocomp curve. A suitable example would be the introduction of PCs or mobile phones, both of which require more complex institutional support, and, in their early days at least, increased agent complexity.

The set of different possible trajectories that an evolving economic system may trace out can therefore be analyzed in terms of different relative costs of carrying complexity in agents and institutions. In Figure 3 below, we decompose the comparative statics of this process into the conventional notions of income and substitution effects. Beginning at point E, a fall in the carrying cost of agent complexity induces a shift of the equilibrium to point F. The substitution effect is represented by E–D and the income effect from D–F.

The decomposition technique of income and substitution analysis may provide helpful insight into policy formation. For example, by indicating the full magnitude of the uncompensated substitution path (E–D) as distinguished from the relative shift in overall complexity, we might better understand how to structure industrial transitions and the sort of agent and institutional support they actually and properly require. This same sort of analytical reasoning may also be applied to the management of change in businesses, as about the balance between centralizing and decentralizing a process of rule substitution, as say the process of adaptation to a new market or technology or some such. In essence, substitution effects measure the cost of change, and income (or wealth) effects measure the gain from change. Clearly, without full elucidation of the analytical meaning of a complexity measure (i.e. its metrical status, its second order functions, etc), these concepts are still somewhat conjectural. But they do hint at the possibility of a welfare analysis of evolutionary economic processes.

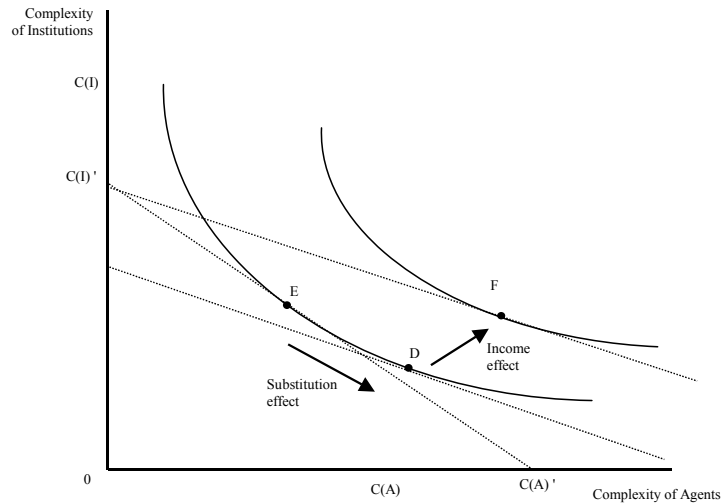


Figure 3. Income and substitution effects traced out by different relative costs of carrying complexity. A reduction in the relative carrying cost of complexity in agents induces a shift in overall complexity. This can be decomposed into an income effect and a substitution effect.

There are other aspects of this framework that we might explore. For example, Figure 4 below illustrates how we may represent the dynamical path of a complex evolving system by constructing this as a meso trajectory of relatively constant complexity embedding, so forming, as mapped through ORD, an evolutionary ‘contract curve’ of system coordination. Unfortunately, time and space do not permit us to go much further here. What, for example, is the nature of the factors that determine relative cost of embedding, or the manner in which complexity is structured in an aggregate system? Does the network classification of the system matter? I.e. does the shape of the isocomp depend upon whether we are dealing with a small world or scale-free network? Does the distribution of complexity over a population of agents matter? (For we have implicitly here assumed a kind of representatively complex agent.) The analytical framework is far from refined yet and much theoretical work remains to be done (some might say started).

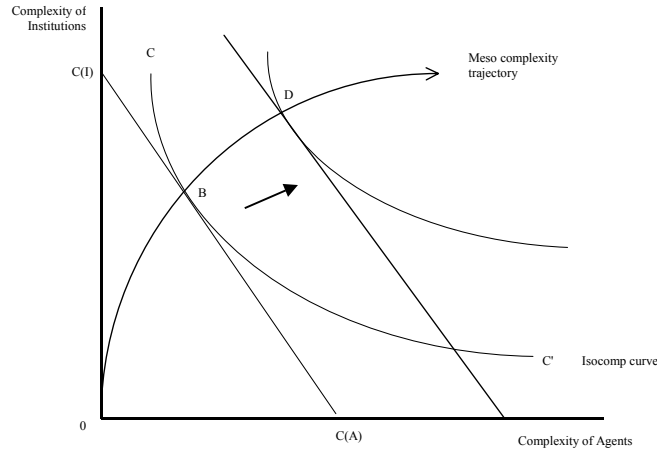


Figure 4. A shift out in the budget line for carrying complexity along a meso trajectory. The introduction of a new meso rule that is agent-institution neutral corresponds to a shift out in the budget line and therefore to a new tangency condition on a higher isocomp (from B to D).

Isocomplexity theory is a method for analyzing evolutionary economic processes at the level of rule substitution between classes of carriers as a function of the relative price of doing so. In this way, relative prices determine meso evolutionary trajectories and, at a deeper level, meso trajectories determine relative prices. All of this can serve to elaborate the micro–meso–macro framework.

Caveat Emptor. As much as we would like to say that there are a great many obvious ideas here that we have already developed that but for time and space constraints shall not present, the fact of the matter is that isocomplexity theory is and remains a hypothetical concept. Isocomplexity theory seem to us to be intuitively coherent, but it might not be. It might also not be of analytical value. So let us be clear: we authors of this theoretical proposal (Potts, Morrison and Clark) see ourselves as peering through a glass darkly about what this treatment of complexity in evolving economic systems might ultimately mean. Still, we are optimists. The basic analytical and metaphorical transfer seems to us to be sound, and although there are challenging problems with the framework – such as the meaning of complexity as a measure – such problems may find resolution. We have provided here no formal nor empirical treatment. No *reason* to believe. Yet we think that isocomplexity theory is worth investigating as a potentially useful analytical framing device. But we will not know whether this is or is not the case until further attempts are made to apply it to the problem domain of evolutionary economics, management science and complexity theory. So, let us round out this presentation of ‘theory’ with a sketch of the domains of economic problem that isocomplexity theory may be applied to.

6 Applications

Rule complexity is allocated between carrier dimensions as a function of the relative price of embedding said rule complexity into each carrier dimension. Complexity goes where incentives tell it to go. Yet in economic evolution, this is something that happens at many levels simultaneously. We propose that three broad isocomplexity instances span the domain of evolutionary economic analysis. They are (1) the micro–micro, (2) the micro–meso, and (3) the meso–macro. Each analytical domain is characterized by a conceptually and empirically interesting analytical state space of complexity-equivalent rule substitution relations. We set these out in turn below. Needless to say, these conjectures of analytical dimensioning are still somewhat tentative notions. Yet allow us to speculate on how this might be applied.

In our view, complexity is a property that applies to many different levels of an economic system simultaneously. That, in general, is what it means to assume complexity. And from that ontological and analytical assumption, we may begin to construct particular theories and models. We suggest that there are three basic domains of application of complexity in economic systems. These are: firstly the

complexity of the agent (micro–micro); secondly the complexity of the agent–environment (micro–meso); and thirdly, the complexity of the environment (meso–macro).

Micro–Micro

The evolutionary economic problem, of how and where to embed meso rules between agents and environment – which is, of course, the essence of the coordination problem, as well as the problem of change – has both micro and macro dimensions. That is the meaning of micro-meso-macro. The macro problem is about how meso rules fit together in the economic system. The micro problem is about how they fit together inside the mind of the economic agent.

Micro–micro, then, is about how economic agents carry meso rules. The two substitute carriers of such rules within an agent are, we conjecture, the instinctual and rational modes of cognitive behaviour. Along this line, we then distinguish conscious processing from habituation, imagination from rationality, experience from learning, as well as other rule classifications in terms of depth of embedding. Some of this is, of course, hardwired into the human genome (Potts 2003, Robson 2003), but much of it is acquired through learning, experimentation, adaptation and other forms of experience (as in behavioural and experimental economics, as well as the theory of learning and of evolutionary games). Perhaps it is possible to use a micro–micro calibrated version of isocomplexity theory to address the evolutionary economics of complex economic behaviour?

The human economic agent is always at or tending toward the complex interface of rule embedding. Disorders arise outside of this space, variously psychological, socio-structural or financial. Subject to initial conditions, then, the economic agent will exhibit behaviour somewhere along an isocomp. We may use isocomplexity theory to decompose this relationship, as in Figure 5 below, where the systemic balance of agent rule complexity, and therefore the parameters of information processing and rational action, are determined by the equilibrium of relative price of substantive over procedural rationality.

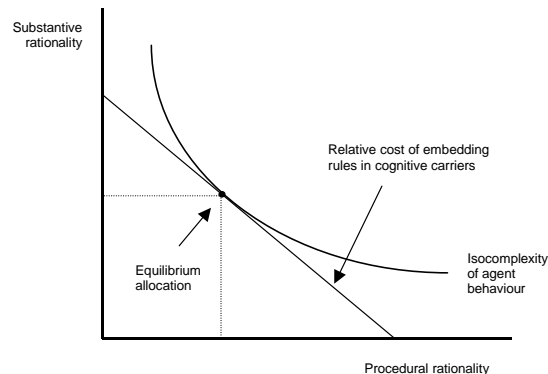


Figure 5. Isocomplexity at the micro-micro level. Behavioural rules are allocated over different levels of cognitive processing (substantive and procedural rationality) according to relative prices.

This model may represent an individual agent, or an aggregate measure of a population of agents (with variation in either the shape or position of the isocomp or budget line). An isocomp is a set of tradeoffs between the substantive rationality of embedded habits and the procedural rationality of rational choice. In this respect, all behaviour is boundedly rational. This is the meaning of complexity in the micro-micro domain, namely that rules can be carried substantively or procedurally.

Evolutionary research in micro-micro theory in evolutionary economics goes everywhere Herbert Simon went, and variously under the name of evolutionary psychology, neuroeconomics, behavioural and experimental economics. It is the study of the meaning of bounded rationality, or of bounded cognition, or even bounded understanding and imagination. The allocation of complexity in micro-micro

is about the study of the algorithms that generate agent behaviour in the economic context of an open evolving system, and, moreover, it is about the empirical nature of these cognitive systems (Potts 2003, Dopfer 2004, Earl and Potts 2004).¹²

Beyond this, when environmental complexity overwhelms both substantive and procedural rationality, we then enter the realm of embedding rules in the external environment – micro-meso – the core of economic evolution.

Micro-Meso

Micro-meso is the ‘classic’ allocation of complexity problem between complexity of agents and complexity of institutions, as represented in Figures 1–4 above. The micro-meso allocation problem is central to much conventionally microeconomic analysis, such as into the internal structure of firms and markets. As above, this can be used as a model of an individual economic agent or as a representation of a distribution of agents in the form of, say, an industry cluster.

There are many phenomena of evolutionary economics and management science that we might integrate here. The study of trust, or of competence are clearly in this realm of embedding rule complexity into the environment. All management science is either how to embed complexity into the environment (e.g. total quality management, just in time delivery, etc) or how to embed complexity into agents (e.g. in search of excellence, training or motivation techniques, etc). And this is also the core of evolutionary economic analysis, and perhaps even of game theory, as the domain of agent choice envisaged by Adam Smith and Ronald Coase alike about the underlying question of what to specialize in and what to contract to others. We may study these effects as shifts in the relative price of embedding rules in different carriers.

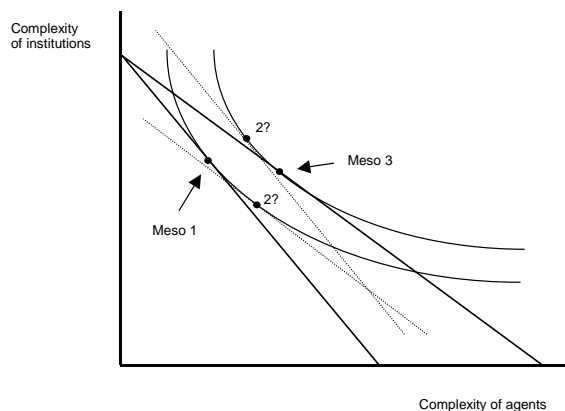


Figure 6. Isocomplexity at the micro-meso level. A meso trajectory or 1 origination, 2 adoption and adaptation, and 3 retention that follows the path of increased rule embedding in agents with corresponding complexity growth.

A further application of the micro-meso model of isocomplexity is in tracking the pathway of a meso trajectory, and, similarly, of either an individual agent or industry cluster. We expect that the comparative static analysis of a meso trajectory will document a sequence of equilibria skewed by a shift in the slope of the budget line, and, through the surplus energy released (or absorbed) through this process, or changes in information processing and in general efficiency of agent interaction, a shift out (in) of the isocomp. There are many questions that might fall under the domain of micro-meso analysis, as about the balance of knowledge between an agent and the environment. And there are just as many about meso-macro, as about how all of these systems of knowledge fit together.

¹² A number of factors effect the cost of embedding; include time, genetics, experience, learning abilities, and so on. The micro-micro model of isocomplexity can be used as a story about a single agent, as in the economics of learning, or as representing a population of agents, as a distribution of acquired abilities and of relative costs.

Meso–Macro

The meso macro domain is between meso units and the macro system, as the meso environment. This perhaps sounds self-similar, and that is the point. The meso-macro is the domain of how rules fit with each other overall. From the perspective of the allocation of complexity, the meso-macro domain is similar to the micro-micro domain, but at an aggregate rather than individual level.

But in the meso-macro framework, an agent rule relates to the capabilities of all agents in an economic system (e.g. Romer 1990 on human capital), and the institutional rule relates to the whole institutional system (e.g. Hayek 1960 or North 1990 on liberal institutions). See also Schumpeter (1945), Loasby (1999), Stiglitz (2002), Foster, Ramlogan and Metcalfe (2004), or Potts (2004). The total complexity of an economic system is carried between its institutional complexity (e.g. Friedman 2002) and the complexity of the agent society underneath, as patterns of geographic, climactic, political, social and cultural factors determine aggregate agent complexity, and the potentials of a society (Diamond 1997, Landes 1998). The basic question here is, what does it take to be an advanced market-capitalist economy? What are the proper historical paths to development?

Evolutionary macroeconomics presents many challenges, from the delivery of proper accounts and occasional revisions of the history of economic growth and development, to a deeper understanding of the nature of aggregate technological change and aggregate expenditure flows and business cycles, among other topics. However, the allocation of complexity framework highlights a major part of macroeconomics that has been systematically overlooked in much formal economic analysis, namely the interaction between the institutions of central and decentralized control. Much of the 20th century unfolded on the back of this debate. Indeed, we may construct the allocation of complexity problem in meso-macro terms as a general foundation for the study of economic history, as a story of alternative complexity embedding in alternative social institutions.

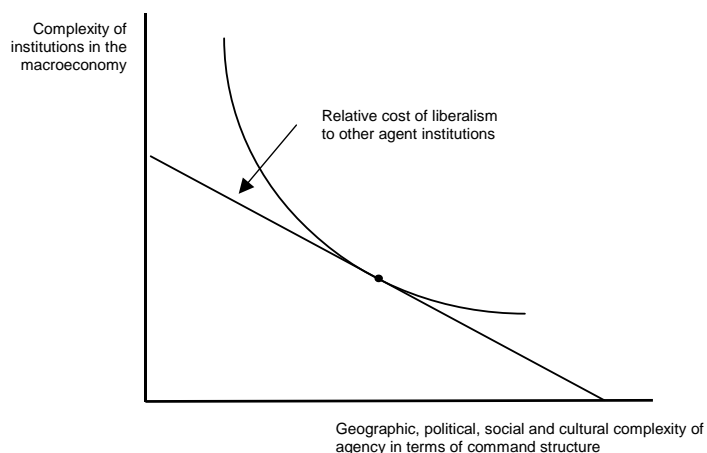


Figure 7. Isocomplexity at the meso-macro level. The relative price of embedding rules in liberal versus other social institutions effects the historical and developmental pathway of a macroeconomy.

These three domains of isocomplexity relations are very different in their domain of application – from the internal workings of the human mind to the structure of institutions that connect millions of agents together into complex socio-economic systems. Yet, the same economic problem underlies each: How best to allocate the generic rules that constitute an economic system to the carrier classes available? We suggest that isocomplexity theory can be used, with both relative ease and conceptual power, to unpack the underlying economics of these complex evolutionary relationships. Or maybe it can't. We shall not know without further investigation.

7 Conclusion

We have proposed here a comparative static methodology for analysis of economic evolution that, following Dopfer *et al* (2004), is conceptualized as a meso rule process. The basic ontological building block of this view is a meso unit: a generic rule and its population of carriers. Economic evolution is defined within this framework as an increase in the rule complexity of an economic system. But, in our view, the essential economic question is: complexity where?

Isocomplexity theory is a way of analyzing the allocation problem inherent in this set-up, namely between changes in complexity in agents and changes in complexity in the economic environment. We have shown how changes in relative prices of embedding complexity effect the evolutionary dynamics of meso rules. Our framework is certainly not original in its underlying conceptual or technical aspect, and owes much to the likes of Marshall, Samuelson, Keynes and others. Yet our innovation has been to conceptualize an allocation of complexity problem (and an associated function, the isocomp) as a problem of comparative statics. We have shown how this methodology can be used to analyse the effects of changes in the relative prices of carrying costs of complex rules, and have indicated how this might be used for analysis of the introduction of novelty under varying circumstance.

While the analytical implications of this theory are not perhaps potentially without significance, the mainspring of our gambit here is methodological. Complexity exists at many levels of the economic system at once, and at each level the same underlying problem of the allocation of complexity over carriers remains. Complexity is a general evolutionary economics solution concept. Yet, as long as there have been evolutionary economists, there has been hostility to the comparative-static methodology and a studied indifference to the concept of equilibrium. We have endeavored to show in this paper that the core neoclassical methodology still has a role to play in evolutionary economic analysis. The simple reason is that evolutionary economic analysis is both evolutionary analysis and economic analysis.

Using techniques described in this paper, we have sought to re-integrate market economic analysis back into the theory of rule-based economic evolution without compromising its underlying ontological and analytical posture. Sometimes attempts to please everyone end up pleasing no one. We hope this is not the case here and invite both neoclassical and evolutionary economists to consider meeting us half-way on this one: rules and their evolutionary dynamics matter, but so too does the relative costs of substitutable alternatives. The outcome, under competitive conditions, is the evolutionary path of an economic system and the distribution of value between public and private endeavour.

We have connected neoclassical economics to evolutionary economics by redefining equilibrium in terms of evolutionary scarcity. From the evolutionary perspective, complexity is a scarce resource, and is allocated accordingly. By maintaining an ongoing balance between variation and selection, and through maximizing the throughput of energy and information, evolutionary competition maintains complexity in an open system. The maintenance of complexity involves the continual sorting of the organization of rules under the constraint of relative prices of embedding in different parts of an artificial, fungible system. The economics of complexity is that complexity will be allocated to where it can best be carried as determined by relative prices, public policy and entrepreneurial imagination.

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