THE ANATOMY OF EMERGENCE, WITH A FOCUS UPON CAPITAL FORMATION

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Abstract:

Emergence is a unifying theme of both evolutionary economics and complex systems theory. In spite of this centrality, emergence in economics has not been subject to an extensive critical analysis. This paper remedies this deficit by providing the first systematic and comprehensive investigation of the nature of emergence in economics. We identify several conditions that emergent economic patterns or rule-systems must satisfy to qualify as emergent: 1. Materiality (system elements have physical properties); 2. Coherence (pattern is not a mere aggregate but a systemic whole); 3. Non-distributivity (pattern possesses global properties absent from its parts); 4. Structure dependence (systemic properties depend upon connective structure). These four core features are common to all forms of emergence in economics. Evolutionary economic systems also exhibit extra-strength versions of emergence, which require that patterns possess one or more additional features: 5. Genuine novelty; 6. Unpredictability in principle; and 7. Irreducibility. We introduce three basic forms of emergence that occur in economic systems—weak, diachronic and synchronic emergence—and apply these ideas to capital formation at all levels of economic order. The economy-wide capital structure exhibits strongly emergent properties (both diachronic and synchronic) that depend on its structural and functional organization; it is not a mere aggregate of capital goods. Within the realm of capital phenomena, we also compare the distinguishing characteristics of emergent and spontaneous (self-organizing) orders, and investigate the subtle and sometimes stark differences between these two types of orders.

Key words:

Emergence, evolutionary dynamics, complexity, capital, production, systems, ontology.

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> Add successively as many mail coaches as you please, you will never get a railway thereby.
>
> (Schumpeter 1934: 64)

1. Introduction: Why emergence matters

Economics is at the dawn of a new age, "the complexity era", which is organized around a vision of the economy as an evolving complex system (Colander et al. 2004, 2009; Beinhocker 2006). Emergence is a key generic property of such a complex adaptive system; indeed, it is what makes economies become complex. Economic evolution does not consist in just churning out more and more clones of existing types of goods and services or mere quantitative variation in macro-aggregates. It does not fill up economic space with mass-produced replicas of the same original pattern (Boulding 1966). Economic evolution is fundamentally a process of emergence that perpetually produces novelty—new routines, new competences, new technologies, new firms, new markets and new institutions.

Economists use emergence to address two key questions: (1) what is the nature of order in economic systems? (2) what is the nature of economic change? Applying emergence to tackle the first question involves studying patterns of ordered complexity at multiple levels in the economy and their structural features. It also involves examining the general qualitative characteristics of different types of economic order, including both "grown" orders (e.g. self-organizing markets) and "made" orders (e.g. business firms) (Hayek

1973: 155). Emergent orders not only result from self-ordering processes but also from deliberate organization. Economists use emergence to examine the way in which elements connect and interact to make larger structures and the multi-level processes that coordinate economic activities across space and time. Economic order is an emergent phenomenon that is brought about by the interplay of agents and rule-systems that economize on agents' knowledge of what to do and how to do it.

Emergence also bears upon fundamental questions about the nature of change in economic systems: the general characteristics of economic change, its sources, the conditions in which new kinds of patterns come into being, the interactions and processes that constitute economic change, and the effects that changes in patterns of connectivity can have on the economy as a whole. Emergence sheds light on discontinuities in economic processes, including those associated with "anagenetic moments" when a new level of ordered complexity arises for the first time (e.g. Rosser et al. 1994).

In spite of its pervasiveness, emergence is elusive and nebulous, proving to be "a mysterious, almost paradoxical, phenomenon" (Holland 1998: 2). Indeed, in a wide range of applications, economists often use the term "emergence" as a generic byword so that it becomes "more evocative than precise" (Ioannides 2008: 1). They know that emergence is going on out there in the economy but they cannot pin it down. To add to the confusion, economists tend to mix ordinary and technical uses of the term and to conflate emergence as a process with emergence as a product. Moreover, they sometimes fail to

make clear whether emergence is the phenomenon to be explained or whether it is included in the data of their explanations of some other phenomenon.

Section 1.1 provides an overview of two programs of economic research in which emergence figures prominently as an explicit object of analysis: evolutionary-institutional economics and complexity economics. Even here, the economics literature seems to be an incomplete patchwork of fragmented and contradictory notions of emergence. (See Table 1.) Scholars selectively pick out one or more characteristics of emergent phenomena and ignore other relevant dimensions of emergence. Thus, even though emergence is a central unifying theme of both evolutionary economics and complexity theory, it has not been subject to extensive critical or systematic analysis.

Consequently, this paper aims to remedy this deficit. We provide a systematic elucidation of the nature of emergence by providing a neutral and comprehensive framework that maps out the full scope of emergent phenomena in economic life. We investigate what emergence really is. In what ways are the effects generated by new combinations of things in the economy different from what their constituent parts produce separately? The objective is to examine if and in what sense different types of economic entities can be considered to be emergent. Accordingly, in section 2, we specify systematically the formal conditions for emergence that economic patterns must satisfy to qualify as emergent phenomena.

Sections 3 and 4 apply our framework to show how emergence can elucidate the nature of the capital order, how it is structured, and how capital forms and changes at various levels of complexity. Section 3 identifies three basic forms of emergence that occur in capital structures and other economic patterns—weak, diachronic and synchronic emergence. Weak emergence encapsulates the core features common to all forms of emergence Section 4 compares the distinguishing characteristics of emergent and spontaneous orders of capital, and investigates the subtle and sometimes stark differences between these two types of orders. Such an investigation is important because economists typically conflate these two kinds of patterns.

1.1 Emergence in evolutionary-institutional economics and complexity economics

Emergence is central to the issues that engage evolutionary-institutional economists. (See Table 1.) Indeed, emergence is "the essence of a generalized evolutionary framework for economics" (Potts 2000: 4). Emergence is invoked in explanations of the forces that propel economic evolution—the ongoing generation of novelty and variety upon which selection processes can operate and without which economies stop evolving. Representative works that focus upon emergence include Dopfer and Potts (2004, 2008), Elsner (2007, 2010) and Hodgson (1997, 2000a, 2000b). Evolutionary economists use emergence to study endogenous change in economic systems over time and to explain why and how qualitatively novel phenomena come into being. Consequently, new routines, skills, capabilities, technologies, firms, networks, consumer preferences, markets, conventions and institutions should all be explained as instances of emergence

that arise from within the economic system rather than as external disturbances. More so than any other feature, novelty is the hallmark of emergence.

In abstract analytical frameworks, the emphasis is upon the emergence of new "rule-systems" (e.g. technologies and institutions) at what is called the "meso-level" (Dopfer, Foster and Potts 2004). The meso-level is an intermediate domain of generic rules sandwiched between the micro-level of individual agents and the macro-level of the whole economy. Thus, technological change, industrial clustering, institutional formation and other types of emergent processes are regarded as meso-economic in nature rather than as micro- or macro-phenomena. At the meso-level, emergence is a process that generates new rule-systems by connecting and combining existing systems into larger patterns (Dopfer and Potts 2004: 14). Systems of meso-rules evolve as wholes and as parts of larger wholes. These systems have emergent properties that are not fully reducible to the properties of their elements or their relations (Hodgson 1997: 408; 2004: 179).

Table 1: Perspectives on emergence in economics: a plurality of concepts

Field of economics	Definitions of emergence	Focal characteristics of emergence	Classes of systems exhibiting emergent properties	Paradigmatic examples of emergence
Evolutionary-institutional economics	"Emergence refers to the idea that novel properties may 'emerge' in a complex system that are not reducible to constituent micro-elements at a 'lower level'" (Hodgson 2000a: 112) "Emergence [is] the generation of new association between elements to form a rule" (Dopfer and Potts 2004: 14) "Emergence: A novel property arising into a system in consequence of a specific organization of rules and connections" (Dopfer and Potts 2008: 101) "Emergence, i.e., generation, adoption, and diffusion of a social rule" (Elsner 2010: 3)	Novelty Non-reducibility of emergent wholes to their parts Reconstitutive downwards causation (Hodgson 2002) Meso-status	Complex, evolving systems (Hodgson 2000b) Modular, open, deep systems (Dopfer and Potts 2004)	Processes of variety generation (e.g. innovation) Formation of habits, routines, cultural norms, conventions, money, standards, institutions The formation of industrial clusters, inter-firm networks, technological and innovative clusters Technological change (especially technological trajectories) and industrial dynamics Economic development (endogenous transformation of economic systems over time)
Complexity economics	"We use the term 'emergent' to denote stable macroscopic patterns arising from the local interaction of agents" (Epstein and Axtell 1996: 35) "When the interactions occur at a level of description other than that at which the patterns occur, these patterns are often called 'emergent'" (Durlauf 1998: 157) An emergent property is "not something that is obviously predictable from the properties or the behavior of the individual" elements (Krugman 1995: 26)	Self-organization ("bottom-up" growth) Recurrence (regular patterns) Explanatory reducibility to a few rules Unpredictability from analysis of average individual (Kirman 1992)	Dynamic systems which do not cycle, explode or converge to a fixed point ("broad-tent" dynamic complexity models) Rule-governed systems of heterogeneous, interacting agents ("small-tent" dynamic complexity models)	Complex phenomena in financial markets, including herding behavior, financial bubbles, excess volatility, and volatility clustering Information and trade networks Patterns of residential segregation, class structure Spatial patterns of economic agglomeration at different spatial scales (local, regional, national, global) Urbanization (formation of cities) and hierarchical urban systems comprising higher-order and lower-order cities Complex patterns in interregional and international trade, and symmetry breaking in the global economy (separation of world economy into rich and poor regions)

Hodgson (1997, 2002, 2004) goes further than other economists in attributing *downward* causal effects to emergent institutional phenomena: new emergent rule-systems at a higher level have new causal powers that not only constrain and channel micro-behavior but also transform and even reconstitute elements at lower levels. For example, through socialization and psychological mechanisms such as habituation, emergent institutions can "shape the human material" (Veblen 1899: 246) by fundamentally changing individuals' habits, purposes and preferences (without, however, violating rules governing causal connections among these micro-elements).

Complexity economics also assigns emergence a central role in economic processes. The complexity approach treats the economy as a complex adaptive system that displays emergent properties as it orders itself in space and time.[1] Representatives of the "process-and-emergence perspective" in complexity research include Epstein and Axtell (1996), Axelrod (2001), Tesfatsion (2002), Kirman (1997) and other papers in the same volume by Arthur et al. (1997). In the newer complexity models, emergence is only ever the product of self-organization; there is no "global controller" intentionally bringing about the emergent pattern through centralized intervention. Indeed, the notion of emergent macro-order forming spontaneously through purely micro-level interactions of agents is the leitmotiv of modern complexity science. The newer complexity modeling uses emergence to study a range of self-organizing phenomena, such as the formation of markets, trade and financial networks, social structure, residential segregation, cultural

[1] The complex systems approach to economics is highly complementary to evolutionary-institutional analyses. Indeed, these approaches overlap somewhat as evidenced, for example, by evolutionary economic approaches that employ complexity-science ideas (e.g. Foster and Metcalfe 2001; Metcalfe and Foster 2004; Foster 2005; Potts 2000).

norms, distributions of wealth, macroeconomic coordination, herding behavior and complex patterns in financial markets. (See Table 1.)

Broadly speaking, emergence is a salient property of "dynamically complex" economic systems—systems that do not tend endogenously to a fixed point, a limit cycle, or a smooth explosion (Rosser 1999: 170). Emergence depends on non-linear dynamics within these systems (such as those arising from positive feedback effects). In agent-based models, emergent phenomena occur in *rule-based* systems—systems that can be meaningfully described in terms of rules. Emergence is thus a feature of a process generated by algorithms. Agents are computational objects that interact according to explicit rules encoded in a computer program. In their artificial societies, agent-based modelers can literally "grow" emergent patterns from "the bottom up" *in silico* before our eyes on the computer screen.

Although novelty is a useful heuristic which complexity researchers use to spot potential instances of emergence, novelty itself is not a defining property of emergence in the newer complexity approach (Holland 1998: 5). For example, agent-based modelers generally focus upon familiar, "already emerged" global patterns and search for simple local rules of individual conduct that could bring these patterns about. The goal is to find a set of rules that is *sufficient* to generate "robustly and replicably" the emergent phenomenon of interest rather than to identify the rules that are necessary for it (Epstein 1999: 55). Indeed, the "hallmark of emergence", according to Holland (1998: 2), is this sense of "much coming from little", of complex structures being generated by a few

simple rules. The "generative sufficiency" of the simple local rules (the parts) constitutes the reductive explanation of the emergent macropattern (the whole). Consequently, emergence is regarded as fully compatible with explanatory reduction. Emergent macropatterns are ontologically and causally reducible to micro-level phenomena.

The take-home message from this brief survey is that there is no comprehensive and systematic attempt in economics to examine what emergence actually is. Formulations of emergence have been imprecise, incomplete and not consistent with each other. Complexity economics holds that emergence is fully compatible with explanatory reduction of familiar macropatterns to a few simple micro-rules. Novelty is not the hallmark of emergence. In contrast, evolutionary-institutional economics regard genuine novelty as the defining property of emergence. They maintain that: emergent phenomena are meso-economic in nature and not reducible in an ontological or an explanatory sense; and they may also exert strong downward effects at the micro-level.

2. Formal conditions for economic patterns (systems) to be emergent

Although there is no unified concept of what emergence is, it is possible to identify a cluster of features that commonly delineate various types of emergence. These features will prove useful for distinguishing emergent from non-emergent properties and patterns in the context of layered capital. We suggest that the *core* characteristic features of an

emergent economic pattern (or an emergent system of rules and rule-carriers) include the following:[2]

E1 Materiality: the pattern consists exclusively of material parts—all its parts have physical properties (Stephan 1998: 640; Van Gulick 2001: 7);

E2 Coherence: the pattern is not a mere aggregate but a systemic whole whose components are connected and interact (Bunge 2003: 15, 17; Corning 2002: 22);

E3 Non-distributivity of systemic properties: the entire pattern possesses at least one systemic (i.e. global) property that none of its components has (Bunge 1977: 97);

E4 Structure-dependence of systemic properties: systemic properties of the pattern depend upon the composition of the system (the set of its elements) and its connective structure (the organization of its elements) (Wimsatt 1997: S373).

In short, to be (weakly) emergent, an economic pattern must be a material system having one or more exclusively systemic properties that depend upon the organization of its components. These core features are common to all forms of emergence in economics. As we explain in section 3, economic patterns exhibiting extra-strength versions of emergence that are particularly relevant to evolutionary economics must possess one or more of the following additional features:

[2] We focus the following discussion on emergent *patterns* of capital. The analysis applies *mutatis mutandis* to emergent properties and relations (i.e. qualitatively new types of relatedness).

E5 Genuine novelty: the pattern is a genuinely novel structure that is qualitatively different from the patterns from which it emerges (Humphreys 1997a: S342; O'Connor and Wong 2006: 13);

E6 Unpredictability in principle: the first-time appearance of a new type of economic pattern cannot be predicted (i.e. logically deduced) through a rational procedure (Popper and Eccles 1977: 16);

E7 Irreducibility: the systemic properties of the pattern do not follow from the properties of the system components in isolation or in simpler systems (Stephan 1998: 644).

The conditions for emergent *properties* correspond to those above for emergent *patterns*: emergent properties are instantiated by material systems; they are non-distributive, structure-dependent, irreducible, genuinely novel and unpredictable in principle. Because recent research on emergence in economics emphasizes emergence of patterns rather than emergent properties (Ioannides 2008: 2), we too will focus upon emergent patterns. In what follows, we examine these seven criteria of emergence in detail as they apply to capital formation at different levels of ordered complexity (e.g. individual capital goods, capital combinations within and across firms, and the economy-wide capital structure).

We argue that the overall capital structure is a material system that exhibits strongly emergent properties—it is a whole that is different from the sum of its parts (see Table 2). Capital structures are not mere aggregates of simpler components (i.e. stocks of capital goods). They are not aggregates because their global (systemic) properties are not

independent of changes in the mode of organization of their components. For instance, the global properties of capital combinations vary with rearrangements, substitutions, additions and deletions of particular capital goods; they are not invariant to operations that dismantle and then seek to put them back together. "To be aggregative [i.e. non-emergent], the system property would have to depend upon the parts' properties in a very strongly atomistic manner, under all physically possible decompositions" (Wimsatt 2006: 675). (See Wimsatt (1986) for a formal analysis.) For aggregates, structure does not matter much: "a heap does not cease to be a heap if its constituents exchange places" (Bunge 2003: 29).

2.1 Materiality (E1)

According to the first criterion, every emergent property or pattern of capital must have a material existence. Emergent capital is always instantiated in physical carriers of some sort, such as individual capital goods—"material instruments of production" (Lachmann 1956: 54)—or capital combinations—"material manifestations of production plans" (Lachmann 1986: 63). For our purposes, resources are material if and only if they can undergo changes in a state space—that is, they have at least one property that can vary over historical time (Bunge 1981: 22). From an evolutionary realist perspective, emergent properties and patterns cannot float free from things as immutable abstract entities such as eternal Platonic forms; they are firmly rooted in the spatio-temporal

world.[3] "There is no such thing as an abstract or ideal capital that exists apart from concrete capital goods" (Mises 1963: 503).

Table 2: Emergent properties of capital at different levels of economic organization

Type of capital pattern (and level of organization)	**System description (elements and connections)**	**Emergent economic properties**
Capital goods (S^1)	Technical subsystems bound by structural and functional relations (e.g. a plane's jet engines, electronic systems for navigation and flight control)	Instrumental functionality (the capacity of means (the good) to bring about a particular end through proper use, under normal conditions of operation, in line with normal tokens of the same type of capital good—Hughes (2009)) Scope for multiple uses that can be made of it (i.e. "multiple specificity")
Capital combinations of a firm (S^2)	Assemblage of complementary capital goods that are part of the same production plan (e.g. a specific configuration of aircraft, computers, buildings, know-how, brand-name, raw materials)	Productivity Increasing returns (e.g. due to technical indivisibilities) Idiosyncratic synergy (i.e. combination-specific economies of scope) (Mahoney and Pandian 1992) "Technical rigidity" (invariability of the mode of combination of specific capital goods) (Lachmann 1947: 110)
Overall capital structure in the economy (S^3)	Arrangement of all firms' capital combinations in the economy as a whole that bear relations of structural consistency to one another	Degree of structural integration (coordinatedness in the service streams flowing into and out of capital combinations across firms) Degree of social division of capital

[3] The materiality condition (E1) is consistent with the evolutionary realist ontology proposed by Dopfer (2005) and Dopfer and Potts (2004). They present three axioms intended to capture the core ontological presuppositions of evolutionary economics. In particular, the materiality condition aligns with their "Axiom of Bimodality", according to which all real phenomena are physical (matter-energy) actualizations of ideas or general rules, so that there is no such thing as purely disembodied capital or technology.

The material nature of emergent capital phenomena means that their existence depends upon other things. An emergent property of capital exists only in the individual things (tokens) that possess it and it cannot exist on its own separately from its tokens.[4] There is no emergence out of nothing: "whatever emerges does so in some (complex) object" (Bunge 2003: 17). Thus, to investigate how properties emerge in the context of capital phenomena amounts to investigating how new things with emergent properties arise—as when new capital goods, new capital combinations and new capital structures appear.

2.2 Coherence (E2)

Emergent capital is always a *system* of interacting material resources of production. All systems are wholes, but not all wholes are systems; some wholes are aggregates. To be emergent, a capital pattern must be an "ordered whole"—a structured entity, not a heap of stuff (Lachmann 1977: 32). An object is a material system if and only if it consists of at least two connected concrete things (Bunge 1979: 6). Without connections that create and maintain economic organization, there are no systems of capital resources. These connections make systems of capital much more cohesive and integrated than mere capital aggregates (Bunge 2003: 27). Connections linking capital resources at each level are stronger within the system boundary than across or outside it. For instance, in a capital combination, heterogeneous capital goods stand in relations of complementarity within the framework of an entrepreneur's production plan. Planned complementarity

[4] Armstrong's "Principle of Instantiation" states that for each one-place (monadic) property, *P*, there exists at least one particular token, *x*, such that *x* is *P* (1978: 113). If an emergent property did not have any empirical instances at all, it would not be a bona fide property and would not have real existence

binds together means employed for the same end and the complementary means interact. During production, at least one capital good x_1 acts upon another capital good x_2 and makes something happen. The wind rotates the windmill, which grinds the grain.

In a capital aggregate (X) the individual capital items (x_1, x_2, … x_n) do not act on each other or interact; at least any physical interactions that do occur are irrelevant for the realization of the aggregate. The properties of the capital aggregate are statistics (e.g. sum, mean) of the properties of the individual capital resources which all influence the properties of the whole in the same manner. The state space of the capital aggregate thus equals the union of the state space of the individual capital goods, and so too the history of the capital aggregate ($h(X)$) is the union of the histories of individual capital goods ($(h(X) = h(x_1) \cup h(x_2) \ldots \cup h(x_n))$ (Bunge 1977: 263). If the units of production are homogeneous and perfectly substitutable, then the history of any individual capital resource is a miniature representation of the history of the aggregate. The upshot is that if all capital were a mere aggregate stock of material resources it could not possess any emergent properties, and there would be no emergent capital patterns.

By contrast, in the case of a system of capital resources, the history of each capital good is determined at least in part by the states of other capital goods, so that the history of the whole does not equal the sum of the individual histories of the parts. The reason is that all systems of capital possess global properties of their own that their components lack (see section 2.4 on non-distributivity). Because the individual components do not possess this global property, it cannot be represented in the partial state spaces of individual capital

goods (or of typical or representative goods (Kirman 1992)). Capital combinations of firms are not miniature replicas of the macro-order of capital (Lachmann 1977: 33).

In order to explain the emergence of a systemic capital pattern such as a capital combination, it does not suffice to specify only its composition (i.e. the set of its elements). We must also identify its system structure (i.e. the collection of internal and external connections). To explain diachronic emergence of a particular capital pattern, we also need to identify the particular historical process of assembly that built the structure—that forged connections between capital goods or combinations and brought about the formation of the ordered whole (Harper and Endres 2010).

2.3 Non-distributivity of emergent systemic properties (E3)

The third characteristic feature of emergent patterns is that they possess at least one non-distributive systemic property. "To say that *P* is an emergent property of systems of kind *K* is short for '*P* is a global [or collective or non-distributive] property of a system of kind *K*, none of whose components or precursors [at a lower level-DH] possesses *P*' " (Bunge 2003: 14-15). A property P is non-distributive if and only if for a system, *X*, which has P, then for all components x_i of *X*, it is not the case that x_i has P. For example, *having an M-form structure* is a systemic property because it is possessed by particular business enterprises (e.g. General Motors) but it is not possessed by any component of the enterprise. In the realm of capital, it is relatively uncontroversial that there exist capital combinations and capital structures with non-distributive systemic properties.

(See too Table 2.) The non-distributivity of systemic properties comes for free by virtue of a pattern being a system, because every system has at least one emergent property absent from its elements (Bunge 1979: 40-41; 1981: 28).

2.4 Structure-dependence of emergent systemic properties (E4)

Another feature of an emergent property is that it depends upon the mode of organization of the system's components and their properties (Wimsatt 1997: S373). An emergent property is determined by the system's structure— the way in which different kinds of components are connected together in the system. Hence, a capital combination *X* having emergent property *P* depends upon the properties of its capital goods (x_1, x_2, … x_n) and their arrangement. Emergence is a particular broad "kind of pattern of relationships between a system property or relationship and the organization and properties of the [system] parts" (Wimsatt 2006: 671). In general, emergent properties constitute "a certain class of higher-level properties related in a certain way to the microstructure of a class of systems (El-Hani and Queiroz 2005: 163). The microstructure includes both internal structure (the collection of connections among components of the system) and external structure (the collection of connections among the system components and environmental items beyond system boundaries). The implication is that emergent properties of capital combinations and other capital patterns depend not only on the context-sensitivity of components and their properties to "intra-systemic conditions" but also on their "extra-systemic context-sensitivity" (Wimsatt 1997: S374; 2006: 671). Emergent capital phenomena are thus a function of broad-based connectivity.

2.5 Novelty (E5)

Genuine novelty is a characteristic feature of dynamic emergent patterns. Genuine novelty occurs when things, often of very different kinds, are combined for the first time in a specific domain (Koestler and Smythies 1969). For example, existing capital goods are arranged in new configurations that produce functional effects that are radically different from what the capital goods can produce in isolation. Genuine novelty requires new kinds of relatedness of elements, new types of connections. The novelty generated by emergence is not just quantitative variation in the same kind of property (e.g. change in the size of a population of agents).[5]

Creating novelty requires a generative operation that combines existing elements and an interpretative operation that makes sense of the resulting combination (Witt 2009). The generation of novel capital combinations involves a kind of *fusion* of existing elements into a new and larger pattern that has not previously been manifested in the economy. It configures capital goods into a certain structural and functional unity that they did not exhibit before they were welded to each other within an entrepreneur's production plan. "That which becomes the stuff at a higher level of emergence is never quite what it was at the lower level from which it was derived—otherwise one would have resultants only

[5] It should be noted that novelty is not a sufficient condition for emergence. Many novel phenomena are not emergent in a technical sense. Examples of such phenomena include: a new abstract idea which has no physical instantiation in a material medium, such as in a new artifact or practice; a new aggregate, or a new quantitative value of an existing aggregate; a mere spatial rearrangement of a set of objects that makes no functional difference; and the disintegration or "submergence" of an economic structure (e.g. the collapse of the Soviet Union).

and not emergence" (Morgan 1923: 192-3). Fusion is a diachronic combinatorial process in which things act upon others; it is a "real physical operation", not a formal operation such as set formation (Humphreys 1997a, 1997b). Thus, emergence is limited to the subset of synergistic effects in which new physical wholes are synthesized (Corning 2005: 52). The fusion operation modifies the behavioral trajectory of at least one and more likely both of the capital goods that are made part of the production plan, so that capital goods are modified and transformed by their participation in the combination.

2.6 Unpredictability in principle (E6)

"Unpredictability in principle" is another salient feature of dynamic emergent patterns. In a dynamic world of unexpected change, the overall capital structure forms in a way that is inherently unforeseeable. This feature means that the future emergence (first-time appearance) of qualitatively novel capital patterns cannot be logically derived from present patterns. (See Harper 1996: 108-110.) The emergence of new capital combinations, rules for making them and new forms of organization can never be predicted through a rational procedure. Creative response in business "can practically never be understood *ex ante*, that is to say, it cannot be predicted by applying the ordinary rules of inference from the pre-existing facts" (Schumpeter 1947: 150).

The unpredictability of emergent capital combinations is a direct consequence of the unpredictability of future knowledge. If their knowledge really grows over time, entrepreneurs cannot predict today the knowledge they will acquire in the future (Popper

1963: vi). If they could predict their future discoveries, they would become present discoveries, and the growth of their knowledge (i.e. their learning) would come to an end. Consequently, if entrepreneurs base their capital-goods-combining actions on their knowledge (experiences, expectations), and if they cannot predict their future knowledge (future experiences, expectations), it follows that they cannot predict the capital combinations that they themselves will form in the future either (O'Driscoll and Rizzo 1985: 25, 83). For similar reasons, it is impossible for entrepreneurs to foresee the future combinatorial actions of other entrepreneurs since these too will be based on knowledge and expectations as yet unknown. This implies that entrepreneurs can never make production plans that are perfectly coordinated with the plans of others—some degree of structural inconsistency between capital combinations across firms is a fact of life in a world of structural uncertainty and real time. The implication of qualitative novelty and unpredictability is that the class of emergent properties (or patterns) is an open class: there is no upper limit to the number of emergent properties (patterns) because new properties are continually added to this class as they are instantiated for the first time. The openness of this class means that the framework of property rights to attributes of capital resources possesses some plasticity and cannot be perfectly specified in advance.

2.7 Irreducibility (E7)

A distinguishing characteristic of some extra-strength emergent patterns is that they are irreducible—they have properties and causal powers not reducible to the intrinsic (i.e. non-relational) properties and powers of their parts (Silberstein and McGreeve 1999). For example, the properties of the macro-order of capital cannot be known or deduced ex ante, no matter how complete our knowledge of the properties of its parts, such as firm-level capital combinations. Similarly, the specific productivity of capital combinations embedded in a production plan does not follow from (and cannot be explained away by) the features that capital goods exhibit when they occur in isolation or in simpler kinds of systems. The value created from combining the particular capital goods cannot be deduced from the valued that would be generated if the same goods were used individually or in other combinations. Indeed, a capital good in isolation cannot produce any output and cannot create value (Lachmann 1956: 41). Thus, by itself, a capital good outside of a production plan does not possess the property of productivity. Hence, the productivity of a capital combination is a strongly emergent property that cannot be reduced to or replaced by the properties of the capital goods considered as unconnected elements.

Core capital combinations within the firm are generally nonmodular—it is not possible to determine the emergent properties (synergistic effects) of the core capital combination from the properties of the capital goods in isolation because of the importance of idiosyncratic connections among particular capital goods in creating value (e.g. as in

combination-specific economies of scope and increasing returns characteristics). Each capital good idiosyncratically acts upon the mode of response of the other so that the behavior of each in interaction with the other cannot be extrapolated from their behavior in isolation. This is especially the case when various capital goods are unique, costly or impossible to replicate and thus not competitively available in the market (so that the entrepreneur does not have access to market prices for these inputs). Various kinds of tacit knowledge, human capital and firm-specific routines are good candidates for such idiosyncrasy. Consequently, "idiosyncratic synergy" (or combination-specific economies of scope) is defined as the enhanced economic value (e.g. higher total output) that is specific to the particular combination of certain capital goods that are under the economic control of a single user (especially through ownership by the same firm) (Mahoney and Pandian 1992).[6]

3. Types of emergence in capital patterns

Emergence comes in degrees; it is not a dichotomous phenomenon. Accordingly, not all emergent capital patterns meet all the conditions of emergence (E1-E7; see section 2). There is a gradience *within* the class of all emergent capital patterns (*A*)—a particular capital pattern *x* within *A* can be closer to the prototype (typical member) of *A* than some other capital pattern *y* within the same class. In particular, some capital patterns are *weakly* emergent if they meet all the core criteria of emergence (E1 to E4) but no others;

[6] Langlois and Robertson (1995: 41-43) employ the notion of idiosyncratic synergy to explain the evolution of the boundaries of the firm over time.

other capital patterns are *diachronically* emergent if in addition to the core they possess the properties of being genuinely novel and unpredictable (E5 and E6); and capital patterns are *synchronically* emergent if they possess the property of being irreducible (E7) in addition to the core properties (Stephan 1998). The three basic forms of emergence in capital patterns are compared in Table 3. This table is an organizing framework that is intended as a heuristic set-up to draw out the implications of different types of emergence for capital phenomena. To avoid misunderstanding upfront, it is important to make clear that capital patterns may exhibit both diachronic and synchronic emergence (e.g. a newly formed, synchronically emergent pattern is diachronically emergent too). We discuss this in more detail below.

In short, any capital pattern classified as weakly emergent must be a material system (E1 & E2) possessing at least one non-distributive (E3) and structure-dependent (E4) systemic property, where a systemic property is a global feature absent from its components. Every higher-level thing that is constituted by structured combinations of lower-level things meets the requirements of weak emergence. Hence, this is a very permissive version of emergence since its preconditions are fulfilled by all systemic capital patterns that have a definite structure because their concrete elements are connected in particular ways (Stephan 1998: 639). The minimal conditions of weak emergence (E1 to E4) are of interest because they are common to both diachronic and synchronic emergence of capital.

Table 3: Types of emergent capital patterns at different levels of organization

Level of economic organization	**Weak emergence (WE)**	**Diachronic emergence**	**Synchronic emergence**
	(WE = materiality, coherence, and non-distributivity & structure-dependence of system properties)	*(WE plus novelty & unpredictability)*	*(WE plus irreducibility)*
Capital goods (S^1)	Any mass-produced capital good that is constituted by combinations of lower-level components	First instantiation of new types of capital goods	Instrumental functionality of a capital good cannot be reduced to the physical structure of the good
Capital combinations (S^2)	Standardized and routine capital combinations	First instantiation of new types of capital combinations	Productivity of a capital combination cannot be reduced to the properties of capital-goods constituents in isolation
Overall capital structure in the economy (S^3)	Any pattern of capital use determined by a large-scale multi-agent network of interdependent production plans	Appearance in economy of novel capital structure resulting from temporal causal processes that integrate plans of capital-forming entrepreneurs	Economy-wide structure cannot be reduced to the various capital combinations of different firms

Diachronic emergence of capital occurs whenever a qualitatively new pattern forms in the capital structure, such as a new type of capital good or a new type of capital combination. A diachronically emergent capital pattern possesses novel system properties that result from the system's evolution over time. "If *X* is a class of things formed by evolution from things of class *Y*, then the members of *X* have [diachronic-DH] emergent properties which the members of *Y* do not possess" (Quintanilla 1982: 230). The

diachronic emergence of new higher-level capital patterns is generated by temporally ordered processes of genetic causation (Cowan and Rizzo 1996).

In contrast, synchronic emergence in capital stresses the co-existence of higher-level properties or patterns with properties or patterns available at some lower level. The qualitatively new whole—the larger capital pattern—is not prior to its parts but is synchronously determined by them (Bunge 2009: 19). After its initial formation, the multi-layered order of capital exhibits synchronic emergence at all levels. For instance, once it is established at time *t*, the overall economy-wide capital structure at level S^3 co-exists with, and spatially includes as parts, the capital combinations at level S^2 of different firms interacting with one another in markets. With synchronic emergence, the higher-level property or pattern in the capital structure is composed of lower-level properties or patterns but cannot be reduced to or replaced by these more basic features or entities. It should be noted that the relationship between synchronic capital patterns at different levels is timeless and hence noncausal in character (because time must elapse between a cause and its effect).

The classes of synchronic and diachronic emergent phenomena are not mutually exclusive. Some capital patterns may exhibit both sets of features. The persistence of a capital pattern across time involves both synchronic and diachronic emergence (Humphreys 2008). Even when dynamic re-ordering of capital is going on at lower levels of economic organization (e.g. regrouping of capital goods into new combinations), the overall economy-wide capital structure may nevertheless present itself as a synchronic

emergent pattern at each stage of that process. Furthermore, the first-time appearance of a specific synchronically emergent pattern (with its novel irreducible synergies) is unpredictable in principle and therefore an instance of diachronic emergence (Stephan 2002: 78, 82).

In addition, high-tech, complex capital goods, such as offshore oil equipment and building automation systems ("intelligent buildings"), often possess both diachronic and synchronic emergent properties. Dosi et al. (2003) call these capital goods "complex product systems" because they comprise many interconnected and customized subsystems and components, organized hierarchically. For example, a modern commercial airplane includes such complex subsystems as jet engines and several electronic systems for communication, navigation, flight control, weather and collision-avoidance. Thus, a complex product system such as an aircraft exhibits synchronic emergence because it co-exists with its technical subsystems but cannot be reduced to these components. Complex product systems also exhibit diachronic emergence as new models temporally develop from earlier vintages. Emerging properties occur from one generation to the next, as small modifications in one element of the design require bigger changes elsewhere in the system, including the introduction of more sophisticated control systems and even new materials (e.g. in jet engines) (Dosi et al. 2003: 175). Moreover, the increasing customization of software embedded in these capital goods magnifies their diachronic emergent properties (especially their unpredictability) because it injects a "human, craft design element" (p.175) that shifts production from relatively predictable engineering tasks to much more uncertain processes of design-intensive software

development (p.188). Moreover, the diachronic emergent properties tend to "reveal themselves only at the stage of system engineering and integration, or later during their actual use" (Dosi et al. 2008: 1171).

4. Distinguishing characteristics of emergent and spontaneous patterns of capital

In this section, we examine the distinction between emergent and spontaneous orders of capital, and investigate the relationship between them. (See Table 4.) Although economists often conflate these two types of order (e.g. Klein 1997: 320), the differences between them are sometimes striking, sometimes subtle, and particular capital patterns may be instances of both types. Given the pivotal role that spontaneous-order phenomena play in economic and social life, understanding this distinction is important for economic theory in general, and the theory of capital in particular. (All mention here of emergent or spontaneous orders is to be understood as referring to economic and/or social patterns (i.e. those orders produced through human action) rather than to physical, chemical or biological patterns.)

In the context of capital, emergence pertains to the dependence of system properties at various levels in the capital structure on the mode of composition and organization of lower-level elements in that structure. Emergence occurs at each level of the capital structure where elements are connected to form new systemic wholes (e.g. capital goods, firm-level capital combinations, economy-wide capital structure). For all versions of emergence, emergent *properties* of capital are always systemic properties that characterize a capital pattern as a whole but that are not local properties of system

components. Emergent capital *patterns* are patterns that possess at least one emergent property. Thus, a pattern's having an emergent property entails the pattern's being emergent. "Being emergent" is a property of a capital pattern that arises out of properties of the pattern's properties—it is a *second-order* property of the pattern.

Table 4: Systems-theoretic comparison of emergent and spontaneous patterns of capital resources

	Emergent capital pattern	**Spontaneous capital pattern**
Composition (C(x))	$n \geq 2$, where n is the minimum number of elements in the capital pattern x Changes in n and the set of elements (via substitutions, additions, deletions) induce changes in the capital pattern	n is a large number Capital pattern may persist as n changes and throughout processes that substitute, add or subtract elements
Environment (E(x))	Framework within which agents act may be dominated by concrete and end-dependent rules (e.g. specific instructions that determine people's roles, their ends and means employed)	Framework must comprise abstract and end-independent social rules that apply to all or large classes of agents (e.g. common-law rules of property, tort and contract)
Structure (S(x))	At least moderately complex Structure may be transient: connections among particular elements (tokens) and types of elements may undergo continual change	Extremely complex Sufficiently stable for internal coherence in the face of external change
Mechanism (process of formation) (M(x))	Deliberate assembly and/or self-assembly Resulting capital pattern can be intended or unintended, end-dependent or end-independent	Self-assembly (in particular, the invisible-hand process of genetic causation) Resulting capital pattern is unintended and end-independent because no external agency directs its assembly

In contrast, spontaneous-ordering properties of capital pertain to the particular mode of pattern formation of a particular class of capital patterns—namely, the economy-wide network of capital resources (what Lachmann (1956: 4) calls the overall "capital structure of society"). Spontaneous ordering of capital pertains to the "invisible-hand" process of assembly by which the interplay of numerous actions of many dispersed individuals, pursuing their own interests in the market place, brings about an overall capital pattern without any intervention by an outside designing agency. The capital pattern in the economic system is endogenously created. Hence, whereas emergence can occur at any level, spontaneous ordering mainly occurs at the level of the overall capital structure in an economy rather than at the level of capital goods or capital combinations.

Every capital pattern classified as a spontaneous order will tend to have the following central attributes:

S1 It is a polycentric order—a large-scale capital pattern that is the consequence of actions of many market participants, not of a single entrepreneur or small group (Mäki 1991: 164);

S2 The capital order is unintended and end-independent—the capital pattern is not the result of human intentional design and it has no overall purpose;

S3 The capital order has an abstract character—the overall capital pattern is not directly visible to us, so we require a theory to recognize the pattern and explain how self-organizing principles bring it about;

S4 It is highly complex;

S5 It is socially beneficial in that it helps to coordinate individual actions and promotes the achievement of many individual purposes.

Although the above five features (S1-S5) are necessary for spontaneous orders of capital, these conditions do not need to be fulfilled in order for a capital pattern to qualify as emergent, though many emergent capital structures do exhibit these characteristics.

Spontaneous ordering processes are necessary for the coming into being of the overall capital order of society. The economy-wide pattern of capital resources cannot exist independently of the particular mode of pattern formation (the invisible-hand process) that brings it about. The invisible-hand process is a process of "genetic causation"—a particular type of causal process in which economic agents act purposefully and in which changes in desires (future goals) and beliefs (plans) are causes of actions (Cowan and Rizzo 1996). In the absence of this particular causal process, there can be no capital order in the economic system as a whole (Buchanan 1982: 5).

Any emergent and/or spontaneous capital pattern *x* is a system. Because it is a system, *x* has a definite composition ((C(x) = set of components), a definite environment (E(x) = set of items with which it is connected), a definite structure (S(x)= set of connections) and a definite mechanism (M(x) = process of formation). Hence, the capital pattern *x* is an ordered quadruple <C(x), E(x), S(x), M(x)> (Bunge 1979: 43; 2003: 37). Table 4 compares the distinguishing characteristics of emergent and spontaneous capital patterns by using Bunge's systems approach. Emergence pertains to the relationship between a

systemic property and the *structure* of the system, whereas spontaneity concerns the relationship between a system and its *mechanism* (or process of formation). The two classes of capital patterns (emergent and spontaneous capital orders) have different minimum system requirements that an instance of the pattern must fulfill in order to possess all the characteristic properties of the respective class of patterns. They differ in terms of what composition, environment, structure and mechanism the pattern must have in order to belong to the relevant class of capital order.

When it comes to their composition, there are vivid differences in the minimum number of components that spontaneous and emergent capital patterns require. (This in turn has implications for the degree of complexity that these two pattern types necessarily exhibit.) A spontaneous capital pattern is a large-scale social phenomenon comprising many elements whose movements cannot possibly be directed or comprehended by a single person or group of people. No one has a "window on the whole, not even a glimpse" (Klein 2006: 66). Such a capital pattern is always extremely interactively complex. In contrast, an emergent capital pattern may comprise as few as two elements that could conceivably be inspected and governed by a single agent. Emergent capital orders come in all sizes relative to the social systems in which they occur and the simplest emergent patterns may be only modestly complex. Hence, a capital good (comprising just two components) or a capital combination (comprising just two capital goods) might both be emergent capital patterns. For instance, a horizontal sundial comprises just two physical parts (a planar surface marked with lines and a gnomon (e.g. a thin rod)) but the capital good as a whole will still have emergent systemic properties

(e.g. instrumental time-keeping functions) that none of its parts has. Similarly, a basic capital combination (say, a hammer and anvil combo) is an emergent capital pattern. This combination has systemic properties (e.g. forging, bending and cutting capabilities) that are not local properties of the individual capital goods in isolation. In both of these examples, the systemic properties are qualitatively novel relative to the properties of the system parts and are vitally dependent on the mode of organization of these parts. In neither example can the system property be reduced to the structure of the particular capital pattern.

Emergent and spontaneous capital patterns also differ with respect to the kind of mechanisms (processes of formation) that they require. Whereas spontaneous capital orders rely solely upon processes of self-assembly, emergent capital patterns may result from deliberate assembly or self-assembly, depending upon the system-level of economic order at which the pattern occurs. For instance, capital goods and capital combinations are typically the products of deliberate assembly: they are the results of human intention and planning and have a limited range of specified uses (intended functions). In general, capital goods and capital combinations only exist because the inventor, entrepreneur or producer had a particular purpose in mind when designing the artifact or putting the combination together. Indeed, capital goods and capital combinations are at least partly constituted by the purposes and plans of the agents who create and use them; they are end-dependent (Mäki 1990: 295). Furthermore, the formation of these emergent capital patterns often results from agents following specific, concrete commands that assign individuals to particular places (e.g. engineering department) within a business enterprise

and that determine the functions to be performed, the concrete purposes (ends) to be pursued and the methods (means) to be used.

As we have said, the formation of spontaneous capital orders depends entirely upon processes of self-assembly. The overall capital structure of a market economy is an instance of a spontaneous order. It meets all the criteria S1-S5. The economy-wide order of capital is an "organically" created social pattern that is generated by invisible-hand processes taking place within a price system and a framework of shared abstract and end-independent rules of conduct, such as the rules of the law of property and contract. The resulting order of capital in the economy as a whole is not part of the intentions of any individual agent or group. It comes into existence without any cooperative actions aimed at bringing it about. Because it is not created by an external agency, the capital pattern cannot have an overall purpose—it too must be end-independent (Hayek 1973: 39). In contrast to stable social institutions, such as language, common law and money, which gradually crystallize as persistent spontaneous orders, the formation of overall capital structure is a transitory and recurring spontaneous order, like the formation of market-clearing prices for goods. The capital structure is kaleidic, precarious and vulnerable to unexpected change. Nevertheless it is as spontaneous in origin as any of the freely grown institutions. (This two-fold distinction was first made by Menger (1985: 146, 158).)

Emergent and spontaneous properties can be instantiated in varying degrees by particular capital patterns. For instance, although a capital combination is typically a planned order, the entrepreneur planning it never fully organizes it in every detail. There is still scope

for decentralized decision-making in which other individuals apply their particular skills and localized knowledge that the entrepreneur does not possess. A planned capital pattern may thus have some spontaneous properties but this does not make it a spontaneous order as such, since the *skeleton* of the capital combination is still consciously designed rather than organic (Hayek 1964: 10). (Thus, whereas any capital pattern that possesses at least one emergent property is an emergent capital pattern, any capital pattern that possesses one spontaneous property is not necessarily a spontaneous order.) In addition, even if the first instance of a new type of capital combination is deliberately assembled, its widespread dissemination and adoption in industry and throughout society may be a spontaneous process. Furthermore, it is conceivable that the rules which frame a spontaneous capital order are not themselves of spontaneous origin but are consciously designed. For example, the spontaneous ordering of capital in some agricultural industries is based in part on explicit rules of trading, warehousing, payments, delivery, business conduct and dispute settlement that have been deliberately made by the relevant commodity exchanges.

Spontaneous capital orders can be maintained throughout processes of change that substitute one element for another or that add or subtract elements. Hence, spontaneous patterns of capital may be preserved through changes in their composition (i.e. the set of their elements) and their scale (i.e. the total number of their elements) (Hayek 1973: 53; Lachmann 1956: 59). In addition, physical continuity of the particular elements is not necessary for the preservation of a spontaneous capital order. All that is necessary is that

the structure of connections prevails so that elements of certain types continue to be connected in certain ways.

Indeed, according to Hayek (1973: 39), spontaneous orders "may persist while *all* the particular elements they comprise, and even the number of such elements, change" (emphasis added). Thus, Hayek sees a spontaneous order and its structure as exhibiting a kind of independence from complete changes in its composition over time. Hayek is claiming that spontaneous orders remain invariant under a specified class of dynamic substitutions of their elements – in particular, they exhibit what Humphreys (2008) calls "transient autonomy" in that each spontaneous order forms and is preserved through substitutions of new for existing token-components *of the same type*. In effect, Hayek and Lachmann are arguing that as particular entities undergo change, the connections between them need not change—that is, changes in the composition of a capital pattern do not necessarily result in changes in the structure of that pattern.

However, in contrast to Hayek and Humphreys, some systems theorists regard the invariance or persistence of an order over operations that substitute, add or delete elements to be a hallmark of "aggregativity" (i.e. *non*-emergence)—where aggregativity is the condition of a property of a whole that is "nothing more" than the properties of its parts so that the property of the whole is just a summary statistic of the properties of the parts (Wimsatt 1986, 1997, 2006). In a homogeneous capital aggregate, any number of goods can be substituted by a corresponding number of alternatives of the relevant type, "as drops of water … in a lake" (Lachmann 1977: 198), without affecting the property of

the whole. Unlike aggregates, emergent system properties are not invariant to changes in the set of elements (i.e. composition) of a system because a change in composition of an emergent system will induce a change in the structure of that system, and emergent system properties depend on the structure of connections between elements. Hence, to the extent that they exhibit aggregative properties such as invariance under substitutions of elements, spontaneous orders are the antithesis of emergent patterns (Wimsatt 2007: 353). Accordingly, because it allows for system invariance with intersubstitutability of elements, Hayek's concept of the capital structure of the economy does not entirely shed aggregative features (Endres and Harper 2009).

The final point of contrast between emergent and spontaneous orders is that the latter are treated almost definitionally as socially beneficial (S5) by most economic theorists, notable exceptions being Marx, Keynes and Kirzner. The prevailing view is that spontaneous orders perform a useful function for the society in which they occur and produce things of general benefit to its members (Ullmann-Margalit 1978: 284-285; Barry 1982: 7). Social patterns (such as the "tragedy of the commons") that meet all the relevant criteria except S5 are not typically included in the class of spontaneous orders. In contrast, many emergent orders are also socially beneficial (in the sense of promoting the purposes of those who move within the order), but *being socially beneficial* is not a necessary condition for emergent orders, whereas it seems to be necessary for

spontaneous orders according to most economists.[7] Emergent orders regularly possess the property of being beneficial but they do not necessarily possess it.

5. Conclusion

Emergence is ubiquitous in evolutionary economic processes. Emergence occurs every time there is an appearance of a qualitatively new good, technology, design, routine, organizational capability, firm, network, market or industry. Accordingly, emergence is one of the "big ideas" at the heart of both evolutionary-institutional economics and complexity research. Surprisingly, though, champions of emergence are not at all unified in their characterizations of what emergence is. The economics literature seems to be a motley collection of fragmented and discordant concepts.

This paper rectifies these shortcomings by providing a comprehensive framework for explaining the nature of emergence. It sets out fully and systematically the technical conditions that economic patterns must satisfy to be emergent. When treated with formal completeness rather than in an ad hoc fashion, emergence is shown to be both a product and a process. It has synchronic and diachronic aspects. Emergent economic patterns can exhibit irreducible features, novel and unpredictable properties, and will have a certain kind of causal history. "Every emergence is a stage in some evolutionary process" (Bunge 1981: 30). We also found that the extent to which a particular economic pattern is

[7] Kirzner (1982) argues cogently that the concept of spontaneous order is a "complex idea", and that normative claims about the socially benign character of this order are distinct and separable from claims about the systematic nature of the social patterns generated by it.

emergent is a matter of degree. We found that there is a graded distinction between more or less prototypical members of the class of emergent economic patterns.

Once we have explained what emergence actually is, we can put it to work to explain other economic phenomena. In order to make emergence less mysterious and more accessible to economists, we applied our framework to the study of economic order and change in the domain of physical capital resources. Elucidating the emergent properties of capital contributes to a better understanding of the nature of capital, its structure and the nature of changes in that structure. It sheds light on the preconditions for capital formation and the persistence of capital patterns, including the institutional rules that frame and guide entrepreneurial decisions to create and regroup capital. A systematic approach to the emergent properties of capital aids us in our quest for a fuller understanding of capital phenomena "in all their complexity and multi-formity" (Menger 1994: 12-13). Ongoing study of emergent capital phenomena will enhance our appreciation of the increasing complexity of layers of specialized capital-goods combinations, especially of an indivisible character (e.g. such as broadband telecommunications infrastructure). It brings home how productivity is an emergent property of complex adaptive systems of capital rather than an aggregative (non-emergent) property of a macroeconomic capital stock.

Although economists often equate emergent orders and spontaneous orders, these two types of patterns in the economy differ fundamentally. We compared their defining features in the realm of capital phenomena. The catch-all notion of "spontaneous order"

is much more limited in the scope of economic phenomena that it can explain. For example, it suffers from serious limitations in explaining capital formation at all levels of economic organization, the micro-constituents of capital structure, its concrete forms and other process aspects of capital phenomena (such as submergence and the disintegration of capital structures). Emergence offers a far more promising vista for future research on capital structures. If we really want to understand what brings about the formation of novel capital combinations, the deliberate reshuffling of existing capital goods, meso-level patterns of capital within particular industries, and coherence in capital patterns at multiple levels, we must consider the emergent properties of capital. Future research should extend the application of our framework to cover other types of structure within the realm of capital (such as the structure of property rights to physical capital and the structure of debt-titles and equities in the firm).

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