Complexity Economics

An Overview

Overview

Complexity economics is a new approach to economic science that uses models from complexity theory to look at and model the economy as a complex adaptive system. It is one of a number of new approaches to economic theory that have arisen in response to the limitations of standard economic theory.

In this paper we will be taking a brief overview to the area of complexity economics, highlighting some of its main characteristics and how it differs from a more traditional approach. We start off by talking about how it models the economy as an open system, meaning that it does not need to be in equilibrium. Relaxing this constraint allows us to create a whole new paradigm built on nonlinear systems theory. Within this paradigm, we get a much more complex picture to individual agents, the motives under which they act, what they value etc.

We talk about how a nonlinear framework will allow us to focus more on non-zero sum interactions where value is added or subtracted to the organization through the type of relations between agents - how synergistic interactions can give rise to emergent macro patterns of organization. Next, we talk about how complexity economics understands these institutions as complex networks, where the structure and makeup of the network defines macro-level resource allocation. Lastly, we talk about economic development as a process of evolution, and how this will allow us to better reason about structural qualitative transformations within the whole system as deriving from internal drivers.

Because complexity economics is based upon nonlinear systems theory and standard economics is based upon linear systems theory, they are from a theoretical point of view very different. They are both looking at the same economy but looking at it through different paradigms. Whereas standard economics models the economy in terms of a closed system with homogeneous isolated agents, making rational choices that lead to equilibrium static macro-level outcomes. Nonlinear models present a very different picture. It is a model of the economy as an open system composed of heterogeneous agents with bounded rationality making choices within a particular context, which gives rise to networks of interactions that we call institutions and a macro level non-equilibrium to the economy that is in constant change driven by internal dynamics.

	Key Features	Standard Economics	Complexity Economics
	**Economy**	Closed System	Open System
	**Agents**	Hyper Rational	Diverse Motives
	**Interactions**	Linear/Zero-sum	Non-Zero-sum
	**Institutions**	Additive	Emergent
	**Dynamics**	Static	Evolutionary

Within economics, this will mean that unlike standard economics where the economy is modeled as a closed system, complexity theory will give us a model to the economy as fundamentally an open system. Standard economic models will not describe how the system interacts with other systems external to it such as the social or ecological domains. The economy exists in isolation. If anything is going to be incorporated into the model it has to be represented as being inside the economy. With complexity economics - because we are using open system models - we can think about the economy as one component interacting with other systems within its environment.

Because we are modeling the economy as an open system, there will typically be no single closed form solution. Isolated systems tend towards a single equilibrium. Open systems - because there is a constant input and output of energy and matter - do not tend towards a single equilibrium. They may have multiple equilibria, which is characteristic of nonlinear systems. This does not mean that they are random, they are just governed by different dynamics. What this means is that the end result of our modeling will typically not be a closed form solution, that is to say, an equation. In general - because we are dealing with open systems that are defined not by any equilibrium or equation - we look instead at the local rules under which the elements operate and how these rules interact to give rise to emergent outcomes and this is typically done through computer simulation.

When using this framework we are interested in understanding and capturing the algorithm that the components are operating under and simulating it to derive overall patterns. By components, I mean agents or institutions. If we then want to go on and create a high fidelity model, we will put that algorithm into code. We will then run this computer model in order to get a simulation of the system's behavior over time. If we do all that, we will have all the information we want to know about the system without ever needing an equation. The power behind this technique is one of the basic premises of complexity theory, that is, the idea that simple rules can create complex phenomena. We are defining simple rules and then using the computer to iterate on these simple rules to give us nonlinear interactions and feedback that will generate a model with a structure that is both complex and intricate – a high fidelity representation of real-world economic phenomena.

"The economy isn't just a system that goes to equilibrium, to a state of rest where everything is kind of perfect and all resources are perfectly efficiently allocated, but it is something that is called a complex system more like an ecosystem, the internet or your brain. The economy is a decentralized system with lots of different actors who are interacting through networks, and we have learnt that networks in the economy are incredibly important, and out of all of those individual interactions emerges a set of patterns and behaviors" - *James Bailey*

Non-Zero Sum

We are very much interested also in the interaction between components, unlike standard economics where these interactions have to be additive in order to get general equilibrium - which basically means the relations add or subtract no value to the system and thus can be largely ignored. In complexity economics, we are not trying to get an equilibrium outcome, and thus these relations don't have to be additive. Because this is a nonlinear framework, they can be non-zero sum, which means they may add or subtract value to the system and these non-additive relations will be important to the overall makeup. Because these interactions are non-additive, they are going to give rise to non-equilibrium macro-scale patterns of organization that will have their own internal dynamics and structure and what we called emergent properties. The result of this will be a heterogeneous macro scale topology to the system - what we call institutions.

These internal emergent structures or institutions will add or subtract value to the whole system creating a macro-level disequilibrium. When we allow for non-equilibrium on the macro level, we can start to think about how the whole system changes over time and complexity economics uses the model of evolution in order to describe this macro process of change.

The fact that we define the economy as an open system allows us to talk about non-equilibrium, and this non-equilibrium is our first basic principle; it will structure and define much of the approach taken from here on. In the same way that general equilibrium is central to the overall workings to standard economics, non-equilibrium and non-linearity are defining factors in the whole approach taken by complexity economics. As with linear systems theory, this approach will enable us to capture and model some things and constrain us from modeling and describing other things.

"The standard approach to economics requires a huge dollop of negative feedback or diminishing returns, like a ball in a bowl, put it to one side and the equilibrium is always restored... standard economics is good we understand a great deal in standard economics but it leaves out a lot of things, it leaves out events that propagate through systems, it leaves out whole networks of connections" - *Brian Arthur, Santa Fe Institute*

Because we have an open model that is actually embedded within some real environment, we can begin to recognize the complexity of the real world. As the economics Axel Leijonhufvud once remarked, Neoclassical models give us a view of, quote “smart people in unbelievably simple situations, while the real world involves simple people [coping] with incredibly complex situations.”

The implicit expectation of standard economic models is that agents are seen as almost supercomputers that are able to run an optimization algorithm over thousands or even millions of different choices within a fraction of a second. Complexity economics - based on the idea of simple rules - instead ascribes individuals with only a very finite amount of computing power, what is called bounded rationality, the idea that when individuals make decisions, their rationality is limited by the information they have, the cognitive limitations of their minds, and the time available to make the decision. Bounded rationality tries to capture the fact that economic phenomena, actually at the end of the day, play out in the real world, and this has real implications and limitations. Again this goes back to the fact that we are using a model that allows us to see the system within its environment. Linear systems theory, because it is an analytical framework doesn't enable this. Modeling systems as closed is sometimes a big advantage, sometimes not so. But in this case, it is creating a very large disparity between what empirical data tells us and what the standard models tell us, and central to trying to resolve this is the new area of behavioral economics.

"The features of complexity economics are clear. The economy is not necessarily in equilibrium; in fact it is usually in non-equilibrium. Agents are not all knowing and perfectly rational; they must make sense of the situations they are in and explore strategies as they do this…In this way the economy is organic, one layer forms on the top of the previous ones; it is ever changing, it shows perpetual novelty; and structures within it appear, persist for a while, and melt back into it again" - *W. Brian Arthur, Complexity and the Economy*

Behavioral economics gives us a much-expanded and more complex conception of motives that are driving the individuals as it studies the effects of psychological, social, cognitive, and emotional factors on the economic decisions of individuals. Agents are still seen to be efficiently pursuing their valued ends, but these valued ends can represent a much wider spectrum not just purely industrial capital.

Because we are not constraining our model of the individual towards achieving equilibrium, we can begin to think about the individual agent as being in a real environment embedded within a multiplicity of different networks, each exerting its own force over the agent's behavior, and thus linear causality, where A causes B, begins to break down. The net result of bounded rationality and a complex set of motives means that agents may come to hugely non-optimal economic solutions. This leads to a discussion of what theory of value can this nonlinear modeling framework offer. Because we are looking at the economy within the context of its connections with other systems within its environment, we can begin to recognize the value of those other things that are not necessarily inside the economy. Using analytical methods, we can only ascribe value to anything that is inside of the system. For example, ecological capital is defined within the model as the mining or agricultural industries. It can't have value outside or independent from the economic system.

But when we see these other domains outside of the system and in relation to it, then we can begin to reason about their independent value and how this might translate into primary economic value - utility. As long as we are using analytical methods focused on looking inside the system, we will only be able to ascribe value to anything that is inside the model. When we use synthetic reasoning to create models for the whole environment, we can then ascribe some value to all the different domains and begin to reason about how to create a metric for translating between domains, thus incorporating both extrinsic primary economic value and intrinsic secondary value. And this will be congruent with our model of agents as being under the influence of many different motives and value systems, as they respond to social capital, cultural capital, environmental capital and so on. It is a much more complex model where we are trying to take account of value in all its different forms. Value is not homogeneous, a single price determined by market equilibrium. It is instead heterogeneous, a network of different interacting variables - and with information technology, this is increasingly a practical reality.

Next, we will talk about the interaction between economic agents. This is the domain of game theory, game theory models both zero sum games and non-zero sum games. Zero-sum games give linear solutions and are thus central to standard economics. Non-zero sum games result in nonlinear outcomes, and thus the nonlinear study of economics is mainly concerned with these non-zero-sum dynamics. It allows us to incorporate relations of cooperation or interference into our model. Both will give us non-equilibrium results. Interference between components means some form of conflict between the agents that make the combined system less than the sum of its parts. As an example of this, we might think about price wars between different businesses. Inversely, cooperation is a form of synergistic interaction between agents. Synergies involve the components both differentiating their functions and coordinating them towards the common end. Through synergies, value is added to the composite organization. Through these relations, we get an organization that is greater than the sum of its parts. Synergies form the basis for the process of emergence that gives rise to different levels in the economy with diverse institutions serving diverse functions on these different levels.

"The complexity approach is quite important because it tells us to pass from an axiomatic discipline like economics to a sort of falsifiable science… Personally, I am quite fed up with the idea of an axiomatic discipline" *- Mauro Gallegati, Polytechnic University of Marche*

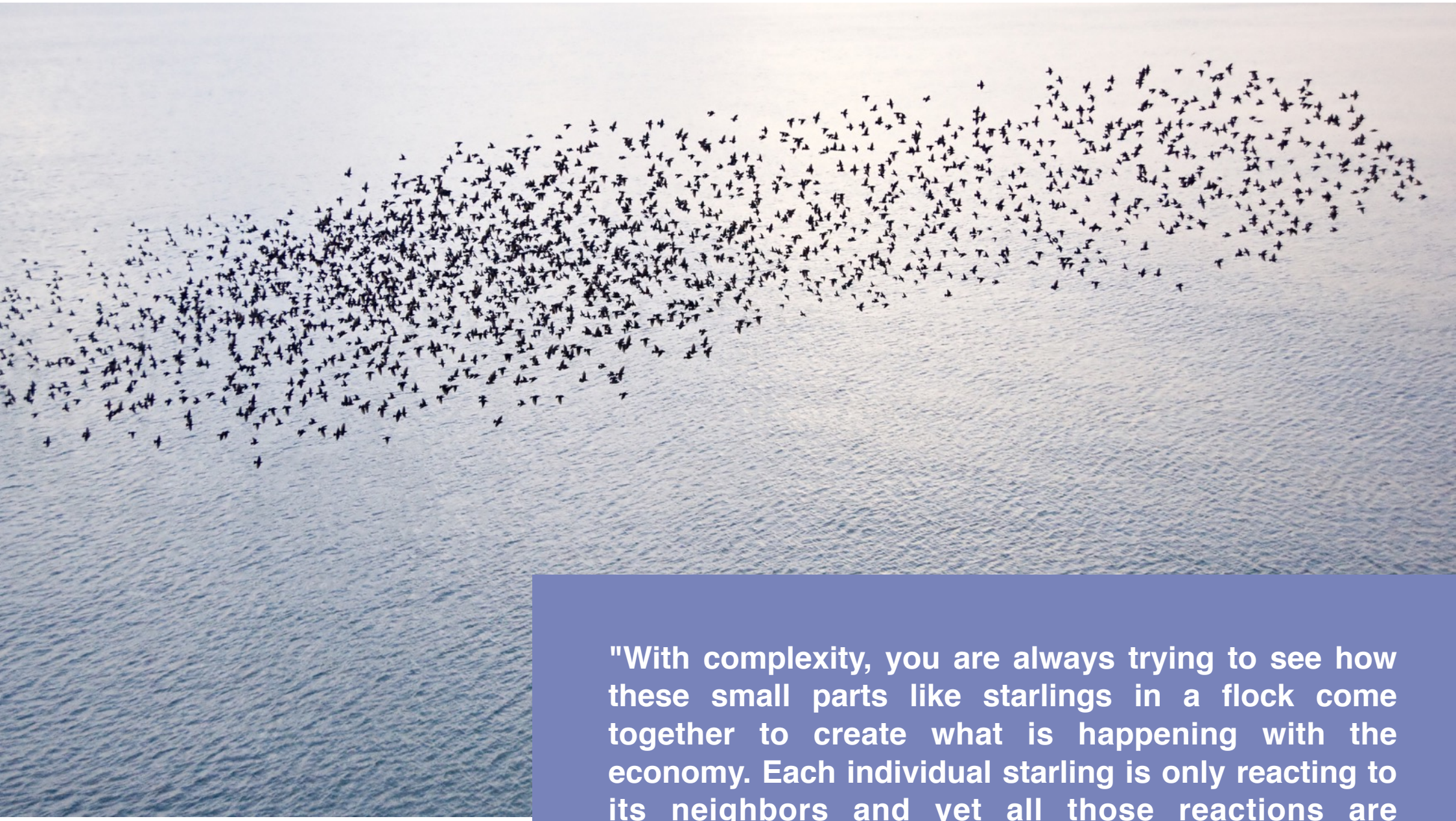
Institutions

In the complexity paradigm, macroeconomic patterns are emergent properties of micro-level interactions and behaviors. But because of the nonlinear interactions between components that we previously mentioned, we cannot analytically derive the properties of the macro system from those of its constituent parts. Although we can apply computational techniques to model the behavior of the emergent properties, that is to say, agent-based models can simulate these emergent phenomena in high fidelity.

When we stop focusing on general equilibrium and the idea of individual atomized agents, and start to focus more on these interactions, what we are going to see is that these institutions are in fact networks, and the structure of these networks is very important because it is going to define how things flow through the network. Because we are dealing with open systems this is about input and output, where a component is in a network, the network's structure and what is flowing through that network is going to be decisive in defining the inputs and outputs to any of its components or subsystems.

Agents within the complex economy are embedded within many overlapping networks, social, cultural, technological, financial etc. How an organization or individual succeeds or fails within this economy is largely a product of these different many interacting variables across different networks and the makeup of those networks. From this perspective, there is no such thing really as efficient markets that allocate resources in an optimal fashion. This whole idea is only really relevant when we are thinking about agents in isolation, agents as price takers in a pure market, where they face an impersonal price structure and they are computing their rational choices.

From the complexity perspective, people are interconnected they are embedded within networks of production and consumption. Resources flow through these networks, and how those resources get distributed out depends on the structure of the network and where you lie in the network. There doesn't have to be any equilibrium here. The distribution of resources across the network can be hugely heterogeneous and may remain in a non-equilibrium state indefinitely.



"With complexity, you are always trying to see how these small parts like starlings in a flock come together to create what is happening with the economy. Each individual starling is only reacting to its neighbors and yet all those reactions are somehow summing up to give the flock"

- Brian Arthur, Santa Fe Institute

Economic Development

Complexity economics sees the economy as a complex adaptive system that evolves over time. In standard economic theory, there is no mechanism for creating novelty or qualitative change within the economy. In the complex economy, the evolutionary process of diversification, selection, and amplification provides the system with novelty and is responsible for the growth in order and complexity over time.

Eric Beinhocker in his book The Origin of Wealth describes this process as “an evolutionary search mechanism. Markets provide incentives for the deductive-tinkering process of differentiation. They then critically provide a fitness function and selection process that represents the broad needs of the population... Finally, they provide a means of shifting resources toward fit modules and away from unfit ones, thus amplifying the fit modules’ influence.”

Complexity economics focuses on the non-equilibrium processes that transform the economy from within, such as technological innovation and new business models created by entrepreneurs that lead to a process of creative destruction, within an economy that is constantly changing as it grows in a somewhat organic fashion. Changes in one part lead to new opportunities and niches within another as the whole thing co-evolves with different industries and sectors becoming interdependent and self-organizing. Out of this process of evolution, we get what we might call economic growth, not so much in our traditional sense of an increase in the gross throughput to the system but more in terms of its qualitative structural transformation in becoming both more differentiated and integrated to exhibit greater complexity.