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Complex Networks in Macroeconomics: A New Research Frontier

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The economist Friedrich Von Hayek, to whom it was awarded the Nobel memorial prize in Economic Sciences in 1974, viewed and interpreted the economic system as an entity governed by a spontaneous order. Such term designates the potential of the market relations to be self-organized, thus not requiring any centralized coordination. Self-interested agents, pursuing their own goals, will form a spontaneous, hence not planned, network of relations that scientists need to carefully analyze in order to acquire a panoramic and solid understanding on how the economy as a whole truly works.

Surprisingly, and despite the advancements on other sciences, e.g, Biology or Physics, concerning the study of network relations, Economics has resisted to adopt network analysis as a mainstream instrument for its research. This happens for several reasons. One of them, perhaps the most striking, is a kind of inertia that prevents economists to escape the straightjacket they themselves have created. Many theorists in this area appear to be fully satisfied with the benchmark model of Economics, and use it to the exhaustion to address every possible issue they are confronted with. Such paradigm is the popular representative agent intertemporal optimization model.

Representative agent models are built upon an extremely strong premise. Namely, they consider that agents not only act rationally, but that they are also able to gather all the available information that is relevant for decision-making. The straightforward corollary of such an assumption is that every agent will produce identical decisions and behave exactly in the same way. Therefore, in this scenario, the macro economy could be characterized taking the behavior of a single average agent, who consequently would be a central planner. In such a worldview, the difference between micro and macro analysis would be just a matter of scale.

A fallacy of composition emerges from the argument in the previous paragraph. In most scenarios, the whole is far from being just the sum of its constituent parts, and it is precisely this simple observation that is leading to a gradual but firm paradigm shift in Economics.

Brunn, Tesfatsion, Bouchaud, Gatti et al., Kirman, Wagner, Bargigli and Tedeschi [1-7] are some of the theorists who claim for the emergence of a new paradigm. According to these authors, the macro economy is a complex adaptive network, where the same micro units might generate different macro outcomes in response to different patterns of interaction. Economic relations are no longer seen as being mechanical; instead, they are the result of strategic interaction by agents who meet locally, leading to unrepeatable complex outcomes and out-of-equilibrium dynamics.

A complexity approach allows for replacing a strict view of rationality by a series of behavioral characteristics one encounters in the real world, namely deliberate experimentation, learning from experience or the ability to adapt to existing social interaction patterns and norms.

The literature on complex networks apparently provides a meaningful setting to study patterns of collective behavior as the ones economic relations involve. A complex network is defined by Boccaletti et al. [8] as a large dimensional, irregular and dynamically evolving organism built upon two sets: a set N, containing nodes, and a set L, composed by links. Thus, basically, in what respects economic activity, a network might be formed by constructing a diagram where each economic unit is a node, eventually associated with other nodes through lines that connect them, with these lines acquiring the designation of links.

Economic networks are truly complex, not only because of the dimension of the network that puts in contact all possible agents within a given universe, but also for several other reasons. First, links may acquire many different shapes, e.g., they can be undirected or directed, they might represent strong or weak ties between two units, and the strength of the connections they represent is likely to change over time. Second, some peculiar and well known complex network forms are well suited to address economic issues, namely, those that relate to small-world networks and scale-free networks [1]. Third, economic networks are, on their essence, dynamic, in the sense they involve relations between agents that adapt their behavior, learn and form expectations on future events.

Most importantly, one should note that economic agents interact locally, i.e., they seldom have an overall and integrated view of the whole of the relevant economic relations; furthermore, their actions are inherently strategic.

Although the application of methods on complex networks is not surely the only possible approach to address the dynamics generated by the relations of interacting agents, such networks constitute a powerful structure of analysis, capable of providing a stylized interpretation of market relations that builds from the particular to the general, i.e., from the micro foundation to the overall perspective on the aggregate or macro behavior.

Complex networks, and agent-based models associated with them, are gaining a deserved place on economic theory and they are, in fact, progressively replacing the benchmark representative agent paradigm. Important contributions concerning the application of methods and tools of complex networks to Economics are gradually starting to emerge, as it is the case of those offered by Gallegatti et al. [9] Gaffeo et al. [10], Bargigli et al. [11], Grilli et al. [12] and Lengnick [13].

So far, the mentioned models on complex networks have approached essentially two topics: (i) Financial contagion. Financial networks allow for studying credit markets and asset markets. The nodes will correspond to the investors and the links will represent

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credit-debit relations; (ii) The organization of decentralized markets of goods and services. In these, nodes represent buyers and sellers and the market structure evolves endogenously given the specific links that the interaction in the network allows for.

In synthesis, one might say that recent literature on the structure and dynamics of complex networks, both the theoretical contributions and the applications to fields that range from engineering to medicine, are paving the way for a new kind of science, less centered on optimal or efficient decisions and more focused on concrete and observable patterns of interaction. A better understanding of interaction processes is particularly vital in macroeconomics, if one truly wants macroeconomics to offer a rigorous account of how the aggregate economy works and performs.

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