

Hyman P. Minsky's unorthodox approach: recent advances in simulation techniques to develop his theoretical assumptions

Abstract: *This paper aims to contribute to the debate on the determinants of financial instability suggested by Hyman P. Minsky. In particular, we discuss the difficulties of analytically addressing his theory and the new scientific frontiers opened by agent-based modeling. Hyman Minsky's work is known as the reference point for several critical strands of standard economic theory. Through these strands, he tries to provide a "financial" interpretation of Keynes's General Theory. Minsky's main research findings converge into the financial instability hypothesis (FIH), according to which in a system based on capitalistic dynamics and characterized by growing and complex financial relations, the economy tends to move from a stable system to a frail one. What causes the economy to become more fragile is derived endogenously from inherent speculative behavior of a financial nature. However, it is not easy to formalize the FIH into a rigorous analytical model. In this regard, we present a survey of Minsky's unorthodox contribution and the recent development of simulation-agent-based models as a new research agenda that can help to model his FIH.*

Key words: *Hyman Minsky, financial instability, uncertainty, agent-based computational economics.*

JEL classifications: *B26, B52, C63, D81, E32, G01*

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The tradition of economic thought rooted in the contributions of Goodwin (1967), Hicks (1937), Keynes (1936), Minsky (1986), and Schumpeter (1954) states that economic instability is a basic structural feature of a sophisticated financial system and that instability crucially affects the system's behavior. In terms of dynamic instability, the effect of this economic framework has been strictly limited to the conceptual and analytical specifications of instability such that the framework's structural implications have been obscured.

Minsky grounded his study on the basic concept of structural instability to coordinate the exogenous determinants of structural change and the system's dynamic behaviors with its endogenous factors. According to this view, the effects of the exogenous perturbations depend not only on their size and nature but also on the structural characteristics of the system because there are well-identified thresholds beyond which the qualitative features of the system's dynamics radically change. In this case, the endogenous factors of the system's dynamics are not limited to disequilibrium dynamics but also include the system's structural features, which may change beyond certain thresholds as a result of the endogenous dynamics, an exogenous perturbation, or both (Vercelli, 2000).

In particular, Minsky's approach is based on a different reinterpretation of the work of John Maynard Keynes, *The General Theory of Employment, Interest and Money* (1936), in that some of Keynes's concepts, such as the decision-making process under uncertainty, the determination of investments, and the cyclical nature of the capitalist economic system, are examined from a perspective that considers the prominent role of the complex financial interactions between banks and firms. The main result of Minsky's research is the well-known financial instability hypothesis (FIH), according to which in a system based on capitalistic dynamics and characterized by a growing and complex system of financial interactions, substantial changes may affect the relationships among the various economic units. Over periods of prolonged prosperity these changes can transform a stable system into a frail one. The factors that cause the economy to become progressively unstable and fragile are derived endogenously from the normal functions of the contemporary capitalist system.

Minsky begins his analysis from theoretical considerations, and he uses analogous tools that are distant from those of mainstream economics. His vision is preanalytical and emphasizes the role of economic instability, which is denoted in terms of structural instability, to reveal the effects of instability on the dynamic behavior of the entire socioeconomic system and its structural changes.

In this work, we reflect on the motivation to ground Minsky's unorthodox approach in the field of a new research stream that utilizes an agent-based simulation as an innovative economic tool. Both of these approaches seem to share a close representation of reality that differs from the model provided by the neoclassical paradigm: the complex interactions that develop between agents and institutions, the evolution of the system over time, the uncertainty of the economic environment, the behaviors of the agents, the study of nonlinear dynamics, the concept of equilibrium, and the bottom-up approach.

Minsky's unorthodox approach

Hyman Minsky conducted his study based on an original reinterpretation of John Maynard Keynes's most significant work, *The General Theory of Employment, Interest and Money* (1936). Minsky reviews some of Keynes's important concepts, such as uncertainty, the determination of investments, liquidity preferences, the business cycle, and to consider the predominant role of the complex financial relationships between banks and firms (Silipo, 1989). Because investments are particularly prone to sudden and violent fluctuations (Keynes, 1937), they significantly depend on the uncertainty inherent to the financial relations between banks and firms. The key factor in the financial instability hypothesis is that the behaviors of banks and businesses change over time. Hence, the distinctive feature of uncertainty strongly influences financial behavior in the portfolio decisions made by the various economic units.

The main problems concerning the market's ability to self-equilibrate are related to decisions that involve the future. For example, the demand for shares, which often grows as the price increases, can create speculative bubbles and induce instability within the financial markets. Under unstable market conditions, some actors engage in speculation to take advantage of price fluctuations. In turn, these speculative activities can exacerbate the intensity of the market's instability.¹

In this regard, John Kenneth Galbraith stated:

As has been so often emphasized, the collapse of the [U.S.] stock market in 1929 was implicit in the speculation that went before. The only ques-

¹ "Speculators may do no harm as bubbles on a steady stream of enterprise. But the position is serious when enterprise becomes the bubble on a whirlpool of speculation. When the capital development of a country becomes a by-product of the activities of a casino, the job is likely to be ill-done." (Keynes, 1936, p. 159)

tion concerning that speculation was how long it would last. Sometime, sooner or later, confidence in short-run reality of increasing common stock values would weaken. When this happened, some people would sell, and this would destroy the reality of increasing values. Holding for an increase would now become meaningless; the new reality would be falling prices. There would be a rush, pell-mell, to unload. This was the way past speculative orgies had ended. It was the way the end came in 1929. It is the way speculation will end in the future. (Galbraith, 1975, p. 187)

Keynes attributes the origins of cyclical fluctuations in investment to changes in the marginal efficiency of capital. In turn, these changes are due to varying expectations. However, Minsky emphasizes the processes of indebtedness that occur between banks and firms. He traces a parallel cycle by utilizing the deflationary process described by Irving Fisher (1933). According to the theory of debt deflation, the main cause of the so-called domino effect is excessive indebtedness. This excessive debt increases the probability that borrowers will become insolvent. After some shocks to the public's confidence in the economy, the debt induces a domino effect that involves the entire economic and financial system.

The people reflect their pessimism about the potential for economic growth by engaging in debt liquidation, which leads to distress selling, a contraction of deposits, and a decreased velocity of circulation. In turn, these effects contribute to a decline in the general price level and an increase in the value of debt for the production system. A still greater fall in the net worth of businesses (i.e., the difference between assets and liabilities) produces the first bankruptcies, which follow reductions in output, trade, and employment. As a result, the socioeconomic system enters a recessionary spiral, where the economic actors' increasing levels of mistrust induce them to decrease their investments and thus further decrease the velocity of circulation. The net effect induced by the deflationary process of prices ultimately manifests itself through profound changes in the interest rates. These changes cause a reduction in the nominal interest rate and an increase in the real interest rate.

However, the economic literature remained almost indifferent to Fisher's analysis (King, 1994) mainly because the described effects were quite limited in response to the greater overall reach of the Pigou effect.

Pigou (1941) called attention to the effects that a general reduction in prices will have on money stocks, which economic agents are used to holding. According to Pigou, this reduction will increase the purchasing power of money, which becomes excessive in relation to the individuals' purchasing habits. In this situation, to resize the real value of money, economic actors will increase their demand for consumer goods and

later influence the demand for investment goods.² Don Patinkin (1956) used the Pigou effect to study the link between monetary and real phenomena and to analyze the reinstatement process that occurs with full employment.

By adopting certain assumptions, such as perfect competition, full price flexibility, and the absence of uncertainty, Patinkin reaffirmed the classical concept of money as a “neutral” entity. In this regard, Federico Caffè stated:

By considering the effects of a price reduction on the real value of money, one implicitly takes into account only so-called external monetary means that were created by an authority empowered to issue currency and use it to purchase goods and services from the private sector. In modern systems, however, money is also created within the private sector, operating through the banking system. Money is that expression of a debt situation in the private sector. But, apart from the distributive effects between creditors and debtors, a general reduction of prices will leave unchanged, in terms of real purchasing power, the situation established by the community. Since modern economic systems use both internal and external money, neutrality of money would be less evident. (Caffè, 2008, pp. 200–201; authors’ translation)

The funding process represents the core of Minsky’s analysis. On the one hand, firms have to resort to bank financing to start their production processes and to purchase capital assets. On the other hand, the normal procedures of the banking system involve the use of short-term deposits (i.e., liabilities) to finance investments in the medium and long term (i.e., assets). This activity is based on the exchange of promises of payment made by customers on a more delayed term through the payment of relative interest. Banks have to evaluate the future profitability of firms (Davidson, 1972) such that firms are able to honor their debts.

Therefore, expectations play an important role in determining the overall trend of the economic system. During boom periods, the overall trend of the economic system induces optimistic expectations that lead the system to reduce its aversion to risk. Conversely, in the presence of pessimistic expectations, the economic trend leads banks to increase their provisions of liquid assets (i.e., liabilities).

Economic actors may also finance activities by using financial instruments other than money. In fact, financial intermediaries are agents who can expand the credit channel by issuing new financial instruments that

² On this point, Leijonhufvud (1968) emphasizes the common awareness of the empirical weakness of the Pigou effect, at least in the short run.

act as currency. In this regard, following the Radcliffe Report of 1959, Kindleberger states how in a developed economy there is “an indefinitely wide range of financial institutions” and “many hold highly liquid assets which are close substitutes for money, as good to hold, and only inferior when the actual moment for a payment arrives” (Kindleberger, 1996, p. 48).

The monetary aggregates are highly sensitive to fluctuations and tend to increase during optimistic periods and to fade during pessimistic periods (Adrian and Shin, 2010; Allais, 1999). This trend led Minsky to conclude that the money supply is endogenous.³ To explain this conclusion, Minsky traced James Tobin’s theory of portfolio choices (1961), which abandoned the hypothesis of perfect substitutability among nonmonetary assets.

Minsky’s analysis introduces a new category of assets, quasi-money, which allows him to describe how the selection process occurs within a wider range of assets. Each asset offers a distinct level of total return and risk. Because Minsky considers both the short-term interest rate and the fact that these assets are not perfect substitutes, the structure of the rates will depend on the supply of the various assets (Wray and Tymoigne, 2008).

In this perspective, choices are made under conditions of uncertainty about the expected future yield of capital assets, so that the prices of capital assets (P_k) are a function of the existing quantity of money (M), the flow of the expected future yield of capital assets (q), the liabilities required to purchase capital assets (c), and the liquidity premium (l) of these assets, which constitute a portfolio choice. This portfolio may be composed of money, quasi-money (e.g., government bonds and savings deposits), securities, and capital assets.

Thus, the P_k function is strongly influenced by subjective views about the prospective yields (q) and the value of liquidity (l).

Unlike the prices of goods, the prices of capital assets are susceptible to sudden and substantial changes primarily because of the nature of stock exchanges, where the securities representing capital assets are continually negotiated and renegotiated. As a result, the structures of investments depend substantially on the operators’ expectations of their portfolio choices and the bankers’ expectations of the variations in the money supply.

³ Nicholas Kaldor (1982) emphasizes that a theory of the value of money, which refers to an economy based on commodity money, does not apply to an economy in which the currency is based on credit. In the first type of economy, the currency has its own independent supply function based on production costs. In the second type, the new currency is formed as the result of or an aspect of the extension of bank credit.

This distinctive system, which is also known as the “Minskyan framework,” has integrated the portfolio choices of agents with the behavior of the banking system. Regarding this aspect, Minsky emphasizes the centrality of the lender’s and the borrower’s risks (Kalecky, 1937; Keynes, 1936).

The lender’s risk is usually objectively determined into a loan contract. It may be due to moral hazard or involuntary default because of disappointed expectations.

For this reason, the lender’s risk involves an increase in the supply price of investment goods (e.g., higher interest rates, closing dates, a pledge to guarantee the loan, and restrictions on dividends and on additional loans). With respect to the borrower’s risk, Minsky underlines its peculiarly subjective nature in the following: “Borrower’s risk is subjective; it never appears on signed contracts. It is a focal point for the ‘quivers and quavers’ of uncertainty and the ‘surprise’ of high animal spirits” (Minsky, 2008, p. 107).

Consequently, the volume of investment is determined by the intersection of the demand curve (taking into account the borrower’s risk) and the supply curve (taking into account the lender’s risk). These two curves play a central role in Minsky’s representation of the state of the economy because during a euphoric phase, both bankers and entrepreneurs become less risk-averse. Entrepreneurs increase their requests for funding, and bankers increase their willingness to grant loans. That is, the two curves become more elastic, whereas the opposite occurs during a crisis. Because variations in the expectations of the lenders’ and borrowers’ risks will determine any changes in the investment levels, the intrinsic presence of factors endogenous to instability can affect the entire system because of the nature of the financial relationships established by the various economic units.

Thus, based on the relation between the borrowers’ operating incomes and debt service payments, we can distinguish three types of finance: hedge finance, speculative finance, and Ponzi finance. A firm belongs to the hedge finance group if the firm’s anticipated operating income can pay both the interest and principal on liabilities. A firm belongs to the speculative finance group if the firm’s anticipated operating income can pay only the interest on the firm’s debts; the firm has to request new loans to repay part or all of its debts. A firm belongs to the Ponzi group,⁴ if the

⁴ Typical Ponzi finance leads to systemic problems, some of which are caused by criminal behavior. However, in Minsky’s framework, Ponzi finance is not necessarily driven by criminal intent, even if such behavior creates the conditions for widespread fraud.

firm's anticipated operating income cannot even pay the interest on its debts. To acquire the needed cash, the firm must either increase its level of debt or sell some assets.

Thus, given the relationship that develops among these three cash revenues (i.e., income, budget, and portfolio) and the firms' commitments to repay a certain amount of debt, the firms' financial structures can be classified into one of three positions: hedge, speculative, and ultraspeculative (i.e., Ponzi). A sharp decline in the value of a firm's expected gains can turn a hedge finance unit into a speculative finance unit. An increase in the interest rates can turn speculative finance units into ultraspeculative finance units and can turn a firm's positive present value into negative present value even if the firm has the same profit expectations. An unexpected rise in the short-term interest rates or a decline in an asset's value may cause the total investment to fail. Indebted firms may find themselves unable to meet their payment obligations, and their creditworthiness may affect the liquidity of the lending banks or financial intermediaries. The lenders' liquidity may be affected if the bank lenders do not renew their loans or if an emergency occurs, such as a "bank run" (Bellofiore, 2009).

The relevance of the economy's cash flows (i.e., income, budget, and portfolio) determines the fragility or the degree to which the financial system is exposed to systemic crises. An unexpected shock can cause a severe debt deflation. This argument is essentially Hyman Minsky's financial instability hypothesis (1974), which states that in a capitalist economic system based on capitalist dynamics and characterized by a growing and complex system of financial interactions, substantial changes may affect the relationships among the system's various economic units. These changes can transform a stable system into a frail one even during peaceful and prosperous eras.⁵ In other words, the ordinary operations of an advanced capitalist economy (Minsky, 1992) cause systems to become increasingly unstable and fragile.

On this point Caffè stated:

Theoretically, this evolution can be expressed through two approaches. On one hand, there is the aspect of economic benefit achieved by switching from more expensive forms of monetary intermediation (such as those of past coins) to less expensive forms (such as those of credit or scriptural

⁵ Because the modern economy is both a capitalist economy, where capitalists aim to accumulate wealth, and a monetary economy, which uses paper money produced without relying on labor, the modern economy is prone to economic crisis. If capitalists believe that the surest way of preserving and increasing their wealth is not producing commodities but rather acquiring liquidity, then an unemployment crisis may occur (Graziani, 2001).

money). Second, there is an innate aspect of instability in credit systems because they are based on trust. These credit systems suffer from both a lack and excess of trust. Therefore, this change of trust gives rise to speculative pressures. In order to be successful, a credit system must be part of an institutional structure that provides it with a brake or support, which may be necessary from time to time. This is a difficult task that, even today, cannot be said to be satisfactorily fulfilled. (Caffè, 1970, p. 29; author's translation)

Similarly, Juglar (1862) stressed how economic shocks are the result of interactions that occur deep within the credit system. The function of a bank is to accept debts with promises of payment. However, if abuses occur during this exchange, then this practice may lead to economic shocks.

In conclusion, confident expectations toward the state of the economy may turn a hedge financial position into a speculative boom. This boom period enables speculation, which results in growing demand for goods and financial assets. If this process occurs, then the economy often experiences an excessive level of trade, which Adam Smith and his contemporaries called "overtrading." This phenomenon often occurs during periods characterized by euphoric expectations and it can increase the likelihood of financial crisis.

Although fascinating, and at first glance compelling, the FIH is not supported by sound theoretical and empirical analysis. On this point, Goodhart stated:

Minsky I find enormously attractive. I think that Minsky's view on the dynamics of an asset-cycle are absolutely right. Minsky's difficulty again was that he was unable to formalize the models that he had into a sufficiently rigorous mathematical format to persuade the rest of profession. . . . The difficulty is that reality is complex and trying to model something so that it is both realistic and yet capable of being modeled formally is very difficult. (Goodhart, 2009, p. 8)

In this regard, we discuss an unorthodox methodological approach that, in our opinion, can help to clarify Minsky's economic thought. Among the alternatives, agent-based computational economics is one approach that has gained more attention and is still judged as very promising.

The motivation of agent-based computational economics

A theory is scientific if it can generate in an irrefutable manner a large number of detailed and accurate predictions that can be compared with empirical observations.

Scientific predictions and forecasts combine reality and theory such that these predications can be verified by facts and directly observed phenomena (i.e., empirical phenomena). A scientific process not only must be repeatable but also must provide any scholar the opportunity to achieve the same results based on the same observations and the same experiments. Furthermore, the process must lead to the establishment of formal theories that can capture the quantitative aspects of phenomena, which are explained through precise and accurate procedures. This paradigm is fully applicable to the “natural sciences” (i.e., physics, chemistry, and biology) but not to the “human sciences,” where hardly any interaction exists between empirical facts and theories. These sciences may be redeemed by simulation methods that, due to the use of electronic processing, provide opportunities to develop new theories (Terna et al., 2006). In recent decades, simulation methods have advanced in this direction. These methods have challenged the theoretical paradigm of neoclassical economics by highlighting some of its flaws and analyzing human behaviors and economic phenomena to discover new scientific paths. Mainstream economics makes several fundamental assumptions about the economic system. First, humans are fully rational when making their own choices. Second, economic theories are explained by equations that try to understand how the values of aggregate variables quantitatively change over time and/or as functions of other variables. This method implies that economic phenomena tend toward equilibrium and remain relatively stable over time. Third, economics is not an interdisciplinary science.

The first challenge is motivated by so-called experimental and cognitive economics, which have been studied by scholars such as Daniel Kahneman and Amos Tversky (1979), Herbert Simon (1983), and Vernon Smith (1976). This particular stream of literature criticizes the empirical accuracy of the assumptions regarding the rationality of humans. These assumptions form the foundation of neoclassical economics. Simon believes that economics should not be concerned with the abstract study of rational behavior but rather must redefine itself as an empirical analysis of the limitations of humans’ computing capacities and the effects of these limitations on actual behavior. Simon notes that a person is more than a rational individual. In fact, people must inevitably face their fallible nature. In its original formulation, experimental and cognitive economics was designed to highlight the individual’s inability to exercise his or her own rationality. This stream of economics also sought to depict the costs of knowledge and information production, which constitute the framework under which rational calculations are performed.

A complementary and equally important step was to recognize the incomplete, asymmetrical, and limited natures of information and knowledge, which represent the basis for decisions made by economic agents (Egidi, 1992).

The second theoretical challenge is more related to the methodology of modern economics. This new stream of economics intends to analyze economic phenomena through a new research tool: computer simulations generated by innovative software, especially agent-based simulations.

The great innovation that has occurred in economic theory is the recognition that economic systems, which the literature aims to model, are complex not because they are prisoners of static equilibriums but because they evolve over time.⁶

Accordingly, Heraclitus (fragment 91) stated, it is not possible to step twice into the same river, nor is it possible to touch a mortal substance twice in so far as its state . . . is concerned" (Robinson, 1987, p. 55). The theory of complexity argues that the reality in which we live is dynamic and evolves in accordance with those who exist within this reality (Arthur et al., 1997). Many new and different economic systems have emerged over time. This diversity is due to the adaptations that these systems have made in response to endogenous and exogenous factors.

Thus, a simulation is different from the traditional tools used to explore reality because simulations attempt to empirically test propositions. A simulation represents a new way of expressing scientific theories, which are no longer limited to being formalized by abstract concepts and ideas communicated through verbal signs. Scientific theories are concepts and ideas that can be used to identify and explain the mechanisms, processes, and factors upon which the phenomena observed in nature are based. Concepts and ideas can then be expressed in a concrete and visible manner through the use of symbolic representations. Other concepts may be expressed via the quantifying symbols used in mathematics. Hence, simulations represent a revolutionary new way to express abstract theories (Terna et al., 2006).

In simulations, one does not use symbols to express a theory but rather a computer program that reproduces the analyzed phenomena. Even in this case, symbols are used to construct the software. However, simulations are fundamentally different from traditional theories in that the symbols are directed by a computer and not by other humans, as is the

⁶ Paul Ormerod (1999) points out the difficulties caused by traditional methods of analyzing the economic sciences and highlights how individuals influence each other in complex ways.

case with traditional theories. If a simulation that was conceived as a theory performs explanations, predictions, and forecasts, then humans need not understand the set of symbols that constitute the program.⁷

The researcher needs only to observe the simulated phenomena, which represent the predictions of the theory, and to compare these phenomena with those observed in reality. Simulations can be viewed as experimental laboratories. Similarly to the phenomena observed in reality, virtual phenomena occur in conditions that are controlled by the scientists. Due to their manipulations, one can analyze and determine how these conditions affect the phenomena. Additionally, one can record the data related to the observed system. Through the use of simulations, one can derive empirical predictions from theories. The virtual phenomena generated by the simulation represent the empirical predictions that will differ in accordance with the scholar's manipulation of the variables.

In their study, Nigel Gilbert and Pietro Terna (2000) affirmed that models belong to three broad categories: literary-descriptive models, mathematical-statistical models, and computer simulations. Previous studies have often used mathematical-statistical models, but according to some authors, these models fail to fully grasp the complexity of the real world. Even if these models permit one to evaluate the consistency and the generalizability of propositions more easily than verbal representations, these models cannot analyze nonlinear dynamics. Therefore, from a methodological perspective, simulations are more likely to be useful. Accordingly, Axtell and Epstein state:

Our point of departure in agent-based modeling is the individual: we give agents rules of behavior and then spin the system forward in time and see what macroscopic social structures emerge. This approach contrasts sharply with the highly aggregate perspective of macroeconomics, sociology, and certain subfields of political science, in which social aggregates like classes and states are posited *ab initio*. To that extent our work can be accurately characterized as "methodologically individualist." However, we part company with certain members of the individualist camp insofar as we believe that the collective structures, or "institutions," that emerge can have feedback effects in the agent population, altering the behavior of individuals. Agent-based modeling allows us to study the interactions between individuals and institutions. (Axtell and Epstein, 1996, pp. 16–17)

⁷ "Simulation is neither good nor bad mathematics, but no mathematics at all" (Ostrom, 1988, p. 384).

Because of their high degree of flexibility, these models are frequently utilized by scholars to simulate social phenomena. In an agent-based simulation, a set of autonomous entities (i.e., agents) represents and provides the model for the social system. Each element in the system has its own characteristics, which are defined by the variables that describe the state. In addition, each element has its own rules for action that can change the state at different times. Thus, a simulated world is a lively and fluid artificial environment that perfectly imitates the reality (Terna, 2003). The structure of a simulation cannot be defined *ex ante* and is only known *ex post* because of the feedback mechanisms that characterize the agents' behaviors.

Given the dualism suggested by the induction–deduction scheme, one can use the agent-based simulation to synthesize simple phenomena and explain the spontaneous “emergence” of regularity from the bottom. This method is profoundly different from the conventional wisdom prevailing in sciences such as sociology or economics, where aggregate regularities that are defined *ex ante* are the result of artificial mechanisms coordinated via a top-down approach. By utilizing a simulation, one bypasses the dual logic of the microstructure and macrostructure. That is, the agent-based models enable the joint study of the whole and its parts as well as the manner in which the parts interact and influence each other.⁸

Agent-based simulation techniques focus on the individual and on the characteristics of local interactions. These techniques mark the border between the use of simulation for forecasting and calculation purposes and the use of simulation to understand and explain phenomena. From a technical point of view, agent-based simulation techniques combine the rigor of analytic treatment with the richness of verbal description. Agent-based simulations can be used in experiments that attempt to describe agents by illustrating the agents' motivations and learning abilities (e.g., classifier systems, genetic algorithms, and neural networks). Furthermore, agent-based simulations can also be used in experiments that attempt to explain the (macro) phenomena generated by the interactions among local agents (Terna et al., 2006). However, the complexity of the interactions and the dynamics emerging from this approach are likely to prevent traditional methods from being used to formulate theories on these phenomena. This particular feature of agent-based simulations has induced neoclassical economists to raise strong objections (Tessfatsion,

⁸ Consider the concept of the Gestalt, which asserts that the whole is greater than the sum of its parts.

2006). As we noted previously, the most frequent objection to agent-based models is their inability to be mathematically formalized, especially as a system of equations that describes in a general and synthetic manner the dynamics of the studied phenomenon. Traditional economic theory moves from a set of definitions and assumptions and proves theorems by using mathematical analysis. One can express the results and implications in the same manner and rigorously conduct analysis if one is working with a system of equations. Conversely, agent-based computational economics (ACE) scholars argue that this rigor is superficial in nature. The results correctly describe reality only if the initial assumptions and selected functions also correctly describe reality. From the ACE scholars' perspective, neoclassical economic models can explain the cause of a phenomenon in a concise and compact manner, but these models generally ignore the possibility that a multiplicity of overlapping and interacting causes can produce important effects.

Some scholars have criticized the use of computational resources because numerically obtained results may be affected by errors. In formal terms, the presence of errors is an element that distinguishes theorems from computational results. Judd (2006) mentions that economists face a trade-off between a lack of specification (e.g., functions and hypotheses) in the analytical models and imprecise numerical solutions.

Joshua M. Epstein (2006) appears to rigorously refute these objections by debunking in a formal, logical manner the three fundamental criticisms aimed at agent-based models: (1) the lack of equations, (2) the use of nondeductive models, and (3) nongenerality.

Nevertheless, it is important to note that the different approaches can be used together. If a phenomenon occurs during a computer simulation, then the phenomenon can be described by a simple analytical model, and if the same phenomenon is identified by a traditional approach, then it can be confirmed by the computational method (Arthur, 2006). Hence, agent-based economics and neoclassical economics should be seen as complementary approaches rather than mutually exclusive frameworks, even though they are built on different foundations (Judd, 2006).

Building a bridge across Minsky's thought and agent-based modeling

Because neoclassical economics identifies the dynamic, driving forces of capitalism as exogenous factors and adopts what Schumpeter calls "the pedestrian view that it is the accumulation of capital per se that propels the capitalist engine" (Schumpeter, 1954, p. 468), Hyman

Minsky utilizes a theoretical framework that differs considerably from mainstream economic theory.⁹ As Gary Dimsky and Robert Pollin observed (1994), Minsky's analysis is a "pre-analytical vision" that calls into question the foundations of orthodox theories, against which Minsky will emphasize the strength of his verbal theory,¹⁰ rather than an analytical treatment providing the same vision (Foley, 2001). Minsky strongly opposes the "paradigm of the village fair," which states that the behavior of modern economies is attributable to the principles of a simple barter economy. In contrast, when Minsky studies an economy with sophisticated financial institutions, he refers to the "Wall Street paradigm" in which key decisions are invariably linked to payment obligations undertaken in the past and to the uncertainty that affects future prospects. By analyzing the economy from a Keynesian perspective, Minsky demonstrates how a financial system tends to endogenously (i.e., without the intervention of external agents) generate a crisis similar to that described by Irving Fisher. According to Minsky, previous analyses of Keynesian thought (i.e., "neoclassical synthesis," which includes the works of Hicks–Hansen, Paul A. Samuelson, Franco Modigliani, Milton Friedman, and Don Patinkin) have moved away from the ideas provided by Keynes's general theory. Minsky illustrates this point:

The work does contain the seeds for a deep intellectual revolution in economics and in the economists' view of society. However, these seeds never reached their full fruition. The embryonic scientific revolution was aborted, as the book's ideas were interpreted and analyzed by academics and then applied by these same academics as a guide to public. (Minsky, 2008, p. 3)

According to Minsky, an authentic interpretation of Keynes's work must focus on the cyclical and financial nature of capitalism. This interpretation considers Keynes's general theory as an analysis of an institutional nature (Whalen, 2001). That is, instead of general rules, one finds typical behaviors and relationships that develop among people belonging to one of many possible economic systems (Kregel, 1976). Minsky argues that the main Keynesian macroeconomic models have completely obscured the essence of the general theory. In particular, the model's need for a simplified socioeconomic reality has led scholars to severely undermine Keynes's thoughts on his most original and revolutionary concepts: the

⁹ His institutional view caused him to adopt an inductive approach when the available deductive strategies prevailed (Mehrling, 1999).

¹⁰ Fioretti (2005) highlights how the concept of financial fragility is intriguing for agent-based modeling because, in terms of a long history of verbal theory, it offers new possibilities in modeling the avalanches of bankruptcies.

decision-making process under conditions marked by uncertainty, the cyclical nature of the capitalist economy, and the financial relations of capitalist economies. In stating, “the fact that it is in the transition that we actually have our being” (Keynes, 1936, p. 343), Keynes attributes an importance to the study of disequilibrium that is completely overlooked by neoclassical theory. Whereas neoclassical models are essentially time-less, Keynes paid great attention to the dimension of time, the transient natures of the various cyclical stages, and the conception of economic activity as a dynamic process. Minsky summarizes this point by stating, “Keynesian economics as the economics of disequilibrium is the economics of permanent disequilibrium” (Minsky, 2008, p. 66).

According to Minsky, the key to interpreting the general theory is Keynes’s answer to a review written by Jacob Viner in 1936. This review was the only occasion on which Keynes contradicted an interpretation of his new work. Minsky summarized the most important aspect of Keynes’s analysis as follows:

What is essential, even fundamental, to any interpretation of Keynes is to recognize that Keynes came to the problems of economic choice that involve time (and thus uncertainty), and the behavior of an economy in which such choices are important, with a sophisticated philosophical framework for examining decisions that are made on the basis of imperfect knowledge, and that this intellectual framework permeated his economics. In addition, Keynes held that there was no way of replacing this uncertainty with certainty equivalents, and furthermore that the relevant probabilistic propositions and the weight attached to such propositions change, not in a random or unpredictable manner, but in a consistent manner in response to events. Decision-making under uncertainty, which Keynes had treated in his *A Treatise on Probability*, is central to *The General Theory*. (Minsky, 2008, p. 63)

In the face of uncertainty and the need to make decisions, we devise conventions, which are outlined by Keynes (Sheila, 2011). We adopt the present as a good guide for the future, and we adapt to the behavior of the majority (i.e., average people). These decisions are subject to “sudden and violent changes” (Keynes, 1937, p. 221) if some action affects the basis of this convention. This concept is appreciated by Minsky, who would place this idea at the center of his theoretical approach:

Two steps have to be accomplished before we can empirically model financial instability. One is to develop a theory in which the properties which determine the relative stability of a financial system and of the economy are endogenous. The second is to define measures on the economy and financial system which can be used to estimate trends in the relative stability of the financial system and the economy. . . . Uncertainty

is the fundamental analytical construct of this theory, and preference with respect to uncertainty as well as units perception of uncertainty are taken to be endogenously determined by the past performance of the economy. (Minsky, 1974, p. 267)

Minsky's theoretical structure of instability should be seen on a level distinct from that of "traditional economists." Although still incomplete, this model provides a solid basis for interpreting the behavior of an unstable economy. However, as we mentioned earlier, this model cannot be categorized as a neoclassical theory. On the contrary, Minsky's model assumes that a partial revolution of the tools used to observe economic reality must occur. Unlike mainstream economic theory, Minsky's work is based on a specific theoretical position. In contrast to the general economic equilibrium, he does not criticize the assumptions about the agents' behaviors but rather criticizes the absence of a time variable and, hence, uncertainty. As Keynes analyzed the importance of the time variable:

The social object of skilled investment should be to defeat the dark forces of time and ignorance which envelop our future. The actual, private object of the most skilled investment to-day is "to beat the gun," as the Americans so well express it, to outwit the crowd, and to pass the bad, or depreciating, half-crown to the other fellow. (Keynes, 1936, p. 155)

Minsky believes that the model formalized by Kenneth J. Arrow and Gérard Debreu (1954) does not consider the main features of capitalism: the ability to speculate on the values of assets and the presence of evolved financial institutions in general (Papadimitriou and Wray, 1999).¹¹ These elements are essential in reality but have no effect on a model that does not account for time. Minsky does not consider the agents of capital markets to be irrational, but at the same time, these agents cannot prescind from their own subjective vision of the economy's future state.

Rational agents inevitably act within a context of Keynesian uncertainty.¹² Thus, Minsky rejects not the hypothesis that individuals behave

¹¹ According to Minsky: "The owners of capital assets speculate by debt-financing investment and position in the stock of capital assets; banks and other financial institutions speculate on the assets mix they own and on the liabilities mix they owe; firms and households speculate on the financial assets they own and on how they finance their position in these assets" (Minsky, 2008, p. 121).

¹² In particular, in an economic condition marked by strong uncertainty, economic choices are not calculable risks. In financial markets, the behaviors of conventional operators can lead to the phenomenon of mass imitation in which the collective behavior of the operators is a rational strategy (Anderson and Holt, 1997; Banerjee, 1992; Bikhchandani et al., 1992).

rationally but the hypothesis that rationality can accurately predict a system's reactions to change. Regarding this madness of the crowds, Keynes highlighted how even apart from the instability due to speculation, there is instability due to the characteristic of human nature, their animal spirits, which mainly depend on spontaneous optimism rather than on a mathematical expectation. (Keynes, 1936).

This view is reiterated with even greater force in George Akerlof and Robert Shiller's (2009) most recent work, which focuses mainly on the thought patterns that animate people's ideas and feelings as key factors in understanding important economic events.

Similarly, Minsky does not criticize the principle of allocating resources via market mechanisms as much as he does the "upstream" procedure (i.e., the principle of coherence in a decentralized economy) (Arrow and Hahn, 1971). Minsky asserted that the problem of coherence in a capitalist economy affects the consumer goods market but not the financial and capital markets. In financial markets, speculative and conjectural elements dominate such that, for example, the increased prices of some financial instruments will increase their demand, which violates the rules of Walrasian equilibrium (Minsky, 1986).

In the *General Theory*, Keynes explains speculation by showing how often stock purchases and sales are driven not by careful assessments of securities but by the ability to guess future price trends. The incoherence of capital markets is particularly evident in times of great euphoria and panic, when prices continue to irrationally follow one direction.¹³ In the presence of Wall Street, a decentralized economy loses its coherence. In such an economy, price reactions to crises depend not only on people's expectations about the future, as mentioned by Keynes, but also on their past decisions regarding the structures of their liabilities and, hence, their payment obligations. This revelation represents the most original idea introduced by Minsky. The financing of capital assets ties subjects to their past decisions and strongly affects the functioning of the economy.

As stated previously, the main drawback of the FIH is that it is very hard to model in any rigorous way. Minsky focused more on qualitative than quantitative representations. This was a deliberate choice and the deeper reason for it could be traced to his skepticism about a formal, statistical method to capture the performance of markets as human and social institutions (Foley, 2001).

¹³ For an interesting digression on irrational exuberance, see Shiller (2000).

Therefore, we aim to reflect on possibilities for grasping Minsky's economic thought in the field of agent-based simulations.¹⁴

In recent years, the development of agent-based modeling (Amman et al., 1996; Axtell et al., 1996; Delli Gatti et al., 2005; Tesfatsion and Judd, 2006) and an analytical tool derived from statistical mechanics (Aoki 1996, 2002; Aoki and Yoshikawa, 2006; Di Guilimi, 2008; Di Guilimi et al., 2011) have opened new frontiers to the micro-foundation of macroeconomics with heterogeneous and evolving agents moving away from the traditional micro-foundations based on the "axiomatic" representative agent (Gallegati and Kirman, 1999; Kirman, 1992).

Gallegati, Giulioni, and Kichiji describe this approach:

It has pointed out the vacuum of the standard (i.e., based upon the representative agent approach) micro foundation literature which is unable to provide sensitive answers to understand a world where, because of less than complete information, agents have to interact. . . . The quantum revolution of the last century, radically changed this perspective: according to the holistic approach it adopts, the aggregate is different from the sum of its component because of interaction. This is precisely the approach the agent based modeling strategy adopts. (Gallegati et al., 2003, p. 9)

Both Minsky and the computer-simulation-based approach appear to share a close representation of reality that differs from the neoclassical model with respect to the following points: the rational behaviors of individuals, the method of estimating economic models, the complex interactions that develop between agents and institutions, the evolution of the system over time, the uncertainty that characterizes the environment, the concept of permanent disequilibrium, and the bottom-up approach.

Minsky comments on the utility of simulation models:

The short durations of crisis means that the smoothing operations that go into data generations as well as econometric analysis will tend to minimize the importance of crises. Because of such factors it might be that the most meaningful way to test propositions as to the cause and effect of financial instability will be through simulation studies, where the simulation models are redesigned to reflect alternative ways that financial instability can be induced. (Minsky, 1972, p. 4)

Following this perspective, Chiarella and Di Guilmi (2010) provide a micro-foundation for Minsky's theory by using two different methods.

¹⁴ "Minsky himself enthusiastically embraced the possibilities opened up by inexpensive computing for exploring 'multi-dimensional, non-linear, and dynamic systems'" (Mehrling, 1999, p. 152).

The first method utilizes a numerical approach that replicates some stylized facts of a real economy, and the second employs a stochastic approximation that can be solved analytically. The results of the simulations exhibit a dynamic consistent with Minsky's idea. That is, the availability of credit leads firms to assume more debt, which causes the economy to grow at a rate significantly higher than its long-run trend. Chiarella and Di Guilmi's framework appears to be an efficient tool for analyzing the effects of instability within financial markets on real economic sectors. In particular, the researchers' framework effectively models investors' expectations to identify the conditions under which the system generates speculative bubbles and the manner in which these bubbles burst.

Lima and de Freitas (2007) developed an agent-based computational model of production through which the supply of credit-money and the cash flows of heterogeneous firms follow a coevolutionary process.

By adopting a set of rules of thumb governing both the behavior of an adaptive banking system and firms' financial positions (i.e., hedge, speculative, and Ponzi), the financial fitness landscape model evolves as an emergent property of that highlighted by Minsky in his FIH.

Lima and de Freitas assert that capitalistic financial structures have an inherent tendency to move from robust to fragile states over time. They believe that the evolution of these structures can be better understood through an evolutionary, complex dynamics approach. Moreover, they argue that Minsky's taxonomy of financial regimes (i.e., hedge, speculative, and Ponzi) can be useful for describing and analyzing the emergence of this characteristic (i.e., the propensity of a market economy with a complex financial system to experience endogenous, self-sustaining fluctuations in economic activity).

Moreover, some Italian authors have recently analyzed some stylized facts regarding the use of an agent-based model to explain complex dynamics, scaling phenomena, industrial dynamics, business fluctuations, and the emergence of financial fragility.

In their analytical treatment, Gallegati et al. (2003) construct an agent-based model in which heterogeneous agents (i.e., firms and banks) interact in the financial market and in which the heterogeneity of the firms is due to the balance sheet, which reflects Minsky's well-known taxonomy of financial regimes (i.e., hedge, speculative, Ponzi). The researchers argued that the micro interactions of artificial agents give rise to complex behavior of the aggregate output, switching from phases of smooth growth to periods of large output variability. The Gallegati et al. (2003) found that recessions and expansions follow different statistical laws (i.e., the rates and lengths of recessions follow a power law, whereas expansions are

lognormal distributed). This finding is mainly due to the fact that firms react differently to both positive and negative shocks. Specifically, the capital accumulation rate depends positively on the firm's equity ratio and negatively on the interest rate.

Therefore, the purpose of the researchers' simulation is to underline the capability of this new tool to mimic a stylized fact with regard to both industrial and aggregate dynamics in accordance with the idea that the ability to mimic real distributions is a signal of sound micro-foundations. The distribution of the firms' size is skewed and described by a power law that shifts over the course of the business cycle¹⁵ (Axtell, 2001; Gaffeo et al., 2003). Cumulative changes of output during the business cycle follow a Weibull distribution (Di Guilmi et al., 2003). Firms' growth rates follow a Laplace distribution (Stanley et al., 1996). The rate at which firms exit is exponentially distributed according to their age (Fujiwara et al., 2003). Bad debt is stretched and exponentially distributed (Delli Gatti et al., 2003). The distribution of profits follows a power law and is characterized by time-reversal symmetry (Delli Gatti et al., 2003; Fujiwara et al., 2003).

In sum, the main insight derived from this line of research is that distributions, individual stochastic levels, and interactions are important (Delli Gatti et al., 2007). Hildebrand and Kirman (1988) comment on the need for a new type of model:

There are no assumptions on . . . isolated individuals which will give us the properties of aggregate behavior which we need to obtain uniqueness and stability. Thus we are reduced to making assumptions at the aggregate level which cannot be justified by the usual individualistic assumptions. This problem is usually avoided in the macroeconomic literature by assuming that the economy behaves like an individual. Such an assumption cannot be justified in the context of the standard economic model and the way to solve the problem may involve rethinking the very basis on which this model is founded. (Hildebrand and Kirman, 1988, p. 239)

Concluding remarks

This paper is devoted to theoretical considerations of Hyman Minsky's thought. We can infer that Minsky utilizes a theoretical framework that differs considerably from the mainstream economic theory. In addition, we find that formalizing Minsky's model through a rigorous analytical treatment is a very difficult task.

¹⁵ Because the firms' size and distributions are described by a power law, the business cycle and scaling behaviors are correlated (Gabaix, 2002).

Mainstream economics may analyze equilibrium under perfect information and perfect foresight and locates the causes of crises in either government failures or shocks, which are exogenous to the functioning of markets. However, drawing on the Keynesian concept of risk and uncertainty as his analytical base, Minsky proposes the financial instability hypothesis in order to bring out the endogenous dynamics of the socioeconomic system. Operating in the world of highly volatile macroeconomic conditions, which are subject to the constantly revised expectations of its agents, financial fragility is an attribute of the financial system and appears even in a normal functioning capitalist economy (Nissanke and Stein, 2003). This paper explores these issues and argues that “time” and the interactions among dynamic balance sheets are crucial to explaining Minsky’s theory of financial fragility. The heterogeneity of economic agents, the endogeneity of expectations, the liquidity and cash flows, and the connections among firms and other economic units through a network of credits and debts could be better analyzed by agent-based modeling. Furthermore, Minsky’s original approach provides a useful and stimulating reflection on the functions and evolution of contemporary financial capitalism. Many of his assumptions and warnings (e.g., securitization) are connected to the economic and financial events of the past few years (Davidson, 2008; Minsky and Wray, 2008). Therefore, we asked ourselves whether Minsky’s financial instability hypothesis could be better investigated by using agent-based simulations to overcome the difficulties of analytically addressing his model.

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