



An agent-based simulation model for analyzing the governance of the Brazilian Financial System [☆]

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ABSTRACT

Regulation can play an important role in effectively managing systemic risk while providing accountability to all affected governments. IMF points out weak governance structures as one of the main causes for financial/economical crisis. However, research in this area is still limited. One of the reasons is the inherent complexity of the public sector governance notion. In this research, the regulatory governance of the financial sector is conceived as a complex system, in which governance is perceived as a phenomenon resulting from the interactions among all the actors that influence or are influenced by regulatory activities within the financial sector. An agent-based simulation was developed to analyze and evaluate the emergent behaviors from the governance in the Brazilian finance sector under different macroeconomics variables and different attitudes, perceptions and desires of economic and political actors. The agent-based model is combined with an econometric model, which is intended to characterize the macroeconomic environment. The regulatory environment is modeled by computational agents using BDI (beliefs–desires–intentions) architecture. The agents have beliefs about their environment and desires they want to satisfy, thus leading them to create intentions to act. The agents' behavior was modeled using fuzzy rules built by means of content analysis of newspapers and in-depth interviews with experts from the financial area. Computational experiments demonstrate the potential of the agent-based model simulation in the study of complex environments involving regulatory governance.

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1. Introduction

The term governance is used in a variety of ways and has several meanings (Rhodes, 1997). Careful analysis of the various definitions or concepts leads to some key-concepts that are commonly expressed. In general, the term implies (Streit & Klering, 2004): (i) the existence of structures, mechanisms and regulations for the exercise of public administration, in different domains; (ii) a new practice within public administration, in which the process is more important than the results, and where emphasis is given to the aspects of participation, transparency, integrity and accountability; and (iii) a new form or structure of public administration, with greater focus on acting through more autonomous, interdependent and regulated networks of organizations or social actors/players, rather than on unilateral, authoritarian, unpredictable and hierarchical governments.

Historically, governance has been seen to be of great relevance for the financial sector. The financial crises in Asia, Russia and in other countries bear witness to the importance and influence of the financial institutions for economic-financial stability. While the circumstances may have been different, the countries involved had distorted governance structures that led to the taking of inefficient economic decisions (Witherell, 2000). The International Monetary Fund (IMF, 2005) points to weak internal governance of banks as one of the main causes of problems for the financial system. A possible explanation is that inadequate governance encourages financial institutions to assume positions involving excessive risk, leaving them vulnerable to macroeconomic shocks. The lack of governance is also associated with corruption, which corrodes the confidence of individuals in public and private organizations and acts as a limiting factor to the investment of foreign capital (Litan, Pomerleano, & Sundararajan, 2002). Therefore, due to the specificities of the financial sector, governance is of unparalleled importance.

According to Litan et al. (2002), governance in the financial sector can be organized into two dimensions: the public and the private. In the public sector, governments normally regulate public institutions and the markets and, in many countries, they also

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directly operate financial institutions. In the private context, governance of the financial sector refers both to the control that the institutions have and exercise over those that take out loans, and the planned practices that ensure the solidity of the institutions themselves. The public and private dimensions of governance in the financial sector are not independent. They are related in a way that is critical for the stability of financial systems.

For the purposes of the present study, the regulatory governance of the financial system can be understood as a complex system, in which governance is a phenomenon that results from the various interactions among all the actors that influence or are influenced by regulatory activities within the financial sector. Hence, governance is exerted through the interactions among social and political actors and entities (individuals, organizations and institutions), as suggested in Kooiman's (2003) framework. The author separates the structural and intentional aspects of the interactions and the relationship between these two levels in order to analyze and interpret governance. Three types of interactions are identified: (i) interference; (ii) reciprocal interactions (reciprocal action and reaction); and (iii) interventions. The interference-type interactions are those that are least organized within society, that is, they are relatively informal. Reciprocal interactions are typically horizontal in nature. In principle, there is no formal authority. The actors seek to achieve collective objectives and participate more or less equally. Lastly, interventions are the most formalized and vertical type of social interaction. They seek to exercise formalized influence, normally by means of legal mechanism, and can be found in all sectors of society, while they are more visible in the public sector.

Application of Kooiman's framework to the Brazilian financial sector shows that the main public body of the government is the Central Bank (known as BACEN, from the Portuguese "Banco Central do Brasil"). It plays a key role, as it is responsible for the regulation and control of the Brazilian Financial System (BFS) by means of the formulation, implementation and application of regulatory policies and supervision of the sector. In the area of monetary policy, the aim of the Central Bank is to control interest rates and the supply of money and credit, in order that they match the needs of economic growth and price stability, while protecting the purchasing power of the currency (BACEN, 2002). To achieve this objective, the main instrument of monetary policy used by BACEN is the definition of the base interest rate of the economy.

Besides government bodies, the other participants in the financial system, such as the banks and institutional investors, also influence regulatory governance within the sector. Their influence is exerted indirectly, as the actors in the private sector do not have the power to regulate. In this case, influence can be exerted by the use of control mechanisms over capital flows, the formation of strong financial groups and participation in the political decision-making processes (Minella, 2003). The role of government is fundamental, but the employment of solid governance practices is the responsibility of all the participants within the financial system.

While the importance of the governance in the financial system has been pointed out in the literature, the difficulty in analyzing this phenomenon is also apparent. As Kaufmann (2002) points out, the research field remains restricted. One of the main reasons for the limited amount of research into the subject is the complexity surrounding the notion of governance in the public area and, especially, within the financial system. The development of a formal model, with the capacity to capture details of the interactions between the elements in the system is difficult (Edmonds, 2003). The use of mathematical models is unfeasible, as they require a level of understanding of the system and its complex inter-relationships, which is incompatible with the present state of the art in modeling complex systems. Unless only a few state variables are used to characterize the system, the computational task of developing a

stochastic nonlinear dynamic mathematical model is impractical (Szilagyi & Szilagyi, 2000). The combined effect of the uncertainty, dynamic interactions and subsequent events, and the complex interdependencies among the variables in the system inhibit the analysis of governance.

According to Gilbert and Troitzch (1999), economists and social scientists are interested in simulation techniques that enable the analysis of models with different levels of abstraction and with the capacity to facilitate vertical and horizontal interaction between such levels. In relation to this requirement, only the autonomous cell and the multi-agent simulation techniques permit this level of communication and interaction among the agents (Epstein & Axtell, 1996). Agent-based models are more powerful in its representation of the internal behaviors of the economic, political and social agents than autonomous cell simulation (Gilbert & Troitzch, 1999). The specific nature of complex systems suggests that multi-agent models, composed of adaptive and computational agents, are useful for predicting, understanding and interpreting behavior (Carley, 2002). According to Lempert (2002), agent-based models are able to represent phenomena that may be difficult to capture with other mathematical formalisms. The author argues that such models stand out because of their capacity to capture the heterogeneous behavior of the agents (different information, different rules regarding decisions, different situations) with the macrobehavior of the system. According to Gilbert (1995), the rules of the agents may be very simple, but the behavior of the system as a whole may be extremely complex. Therefore, multi-agent systems are thought to possess characteristics that make them well suited for explaining and understanding the phenomena associated with the regulatory governance of the financial system. In the literature, several authors (Axtell, 2000; Lebaron, 2000; Mentges, 1999) share similar opinions regarding the potential of agent-based simulation models for the understanding of complex phenomena. One of the reasons for this convergence of opinions concerns the autonomy of the agents.

As the main instrument of governance in financial systems is the base interest rate, the research focus on this relevant issue. Conventional research addressing the estimation of this rate have generally employed the time series analysis techniques (i.e., mixed auto regression moving average (ARMA)) (Kuo & Xue, 1999) as well as multiple regression models. Most only consider the quantitative factors, like technical indexes. Artificial intelligence techniques, like artificial neural networks (ANNs) and genetic algorithms (GAs), were also applied in this area (Franti & Mähönen, 2001; Ju, Kim, & Shim, 1997). However, a number of qualitative factors, e.g., macroeconomical or political effects may seriously influence the interest rate tendency. The agents' perception could result in the index oscillation as well. Therefore, concerning ourselves only to some technical indexes to predict the interest rate is not enough in such a complicated environment. It involves how the involved agents perceive all elements involved (e.g., macroeconomical variables and government's policies), since they do not only consider the technical indexes but also consider qualitative factors based on their experienced knowledge. Thus, it turns out to be significant to capture this unstructured knowledge. Fuzzy logic has been applied in the area of control and has shown highly promising results. This concept attempts to capture experts' knowledge, which is vague. Hence, fuzzy logic appears to be a rather promising candidate for simulating the agents' knowledge.

This study aims at developing an agent-based simulation model for the analysis of the regulatory dimension of governance within the BFS. The agents in the simulation model are autonomous entities that establish their own objectives for the decision-making process and interactions with other agents. The model incorporates the human-like (representing the economical agents) reasoning style of fuzzy systems through the use of fuzzy sets and a linguistic

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